STRATEGIC ENGAGEMENT IN GLOBAL S&T

OPPORTUNITIES FOR DEFENSE RESEARCH

Committee on Globalization of Science and Technology:
Opportunities and Challenges for the Department of Defense

Board on Global Science and Technology
Policy and Global Affairs

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Preface

Over the past several decades, the global science and technology (S&T) landscape has changed, in terms of both scientific output and contributions made by the global, as opposed to national, S&T communities, as well as the means and rapidity by which S&T knowledge is created and shared around the globe. Universities and industries must compete globally to attract the best talent from an increasingly global talent pool. Countries whose S&T enterprises fail to maintain awareness of emerging technological advances and to engage and collaborate with those who lead their fields may find themselves falling behind, with dramatic implications for economic competitiveness and national security.

On the one hand, the globalization of research, of knowledge, and of the S&T workforce presents great opportunities for leveraging investments, sharing costs, and solving environmental and societal challenges that require international coordination and collaboration. On the other hand, it also presents several challenges, including increased global competition, prioritizing international engagement activities as S&T budgets shrink, and overcoming the stigma that the benefits of international collaboration are outweighed by the risks.

The United States' Department of Defense (DoD) has long relied on its historical technological superiority to maintain military advantage. However, as the U.S. share of S&T output shrinks and as the U.S. defense research enterprise struggles "to keep pace with the expanding challenges of the evolving security environment and the increased speed and cost of global technology development,"[1] the DoD must reexamine its strategy for maintaining awareness of emerging S&T developments occurring around the world. To fully leverage these advances and to make strategic research investments, the DoD must assess with whom and in which areas it should collaborate. To delve more deeply into the implications of the globalization of S&T and of international S&T engagement for the Department of Defense, the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), and the Office of the Deputy Assistant Secretary of the Army for Research and Technology (DASA(R&T)) asked the National Research Council (NRC) to assess current DoD strategies in the three Services—Army, Air Force, and Navy—for leveraging global S&T and for implementing and coordinating these strategies across the department. The committee's work was focused on fundamental research, as defined in National Security Decision Directive (NSDD)

[1]2010 Quadrennial Defense Review Report. Department of Defense. February 2010. p. 84.

189[2], and those organizations within DOD and its components for which that is a primary mission. The study did not include the Defense Advanced Research Projects Agency (DARPA) whose main mission is advanced research projects.

The Committee on Globalization of Science and Technology: Opportunities and Challenges for the Department of Defense (GSTOC) was appointed under the auspices of the NRC's Board on Global Science and Technology (BGST) to conduct this exploration. The members of the study committee represent academia and industry and have expertise in the globalization of science and technology, international engagement, the defense research enterprise, program evaluation, and national security. Biographical information for members of the committee is presented in Appendix A, and Box P-1 contains the committee's statement of task. The committee held five meetings during the course of its work (February 2013, April 2013, July 2013, October 2013, and January 2014), and Appendix B lists speakers who provided briefings to the committee during these meetings.

To meet its charge, the committee took a three-tiered approach. First, it provided background and context for the rapid and ongoing globalization of science and technology, as well as the implications of globally emerging S&T for the DoD. The committee then examined current approaches for global S&T engagement and awareness used by the DoD research enterprise, which includes scientists and engineers (S&Es) at defense laboratories and research centers, the Service S&T offices in the United States and overseas, and policy and decision makers at the Office of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) and the Office of the Secretary of Defense (OSD). The committee also visited the Services' S&T field offices to learn how those offices operate and what each of the offices see as the greatest opportunities and challenges for global S&T engagement. The committee then examined opportunities for DoD to adapt or adopt or leverage approaches for international engagement used by S&T organizations across academia, industry, and government. Finally, as a part of its information-gathering efforts, the committee sent small delegations to Asia and to Europe to gain a better understanding of how other countries' S&T enterprises engage in global S&T. Appendix C lists individuals who met with and shared their views on global S&T engagement with the committee delegations. A list of sample questions posed by committee members on their data-gathering visits is provided in Appendix D. A list of abbreviations is provided in Appendix E.

We would like to thank the members of the study committee for their many contributions in developing this report. We also thank the briefers who met with the committee in Washington, D.C., as well as the individuals who met with committee subgroups who travelled to Europe and Asia. These meetings provided valuable insights and input throughout the study process. We also thank the reviewers (see page xi). Lastly, the support of the NRC staff was indispensable to accomplishing this study. Special thanks go to Ethan Chiang, who worked closely with the

[2]Memorandum on Fundamental Research signed by USD/ATL, May 24 2010.

committee throughout the study and played a major role in the preparation of this report.

Arden Bement, *Co-Chair*
Committee on Globalization of Science and Technology: Opportunities and Challenges for the DoD

Ruth David, *Co-Chair*
Committee on Globalization of Science and Technology: Opportunities and Challenges for the DoD

BOX P-1
Statement of Task

An ad hoc committee will conduct an assessment of the opportunities and challenges stemming from the globalization of science and technology (S&T) and the implications for the Department of Defense (DoD) and its Services. The committee will assess current DoD strategies in the three Services for leveraging global S&T and implementation and coordination of these strategies across DoD. The committee may also examine past outcomes of these efforts and the impact these efforts have had on the U.S. Defense S&T enterprise. In addition, the committee will explore models for global S&T engagement utilized by other domestic and foreign organizations. Finally, it will assess how the ongoing globalization of S&T may impact the future DoD mission space (possible examples include research funding and priorities, workforce needs, building and maintaining trusted relationships, avoiding technology surprises, etc.). In addition to findings, the committee may make recommendations for future DoD and Service strategies to better meet the challenges and opportunities that result from the ongoing globalization of S&T.

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank the following individuals for their review of this report: Wanda Austin, The Aerospace Corporation; William Banholzer, University of Wisconsin-Madison; Vance Coffman, Lockheed Martin Corporation (Ret.); Natalie Crawford, The RAND Corporation; Mitra Dutta, University of Illinois at Chicago; Paul Gaffney, Monmouth University; Sophie Laurie, Research Councils UK; Bernie Meyerson, IBM Corporation; Chung-Yaun Mou, National Taiwan University; Brian Schmidt, Australian National University; Sylvia Schwaag Serger, VINNOVA; and David Stonner, National Science Foundation (retired).

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Honorable Malcolm O'Neill, U.S. Army retired. Appointed by the National Academies, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Summary

According to recent reports,[1,2] the U.S. currently accounts for less than one-third of global research and development spending, and it is projected that this fraction will decline to 18 percent by 2050. These statistics, compounded by the recognition that the United States no longer maintains technological superiority across all research fields, highlight the need for the U.S. research community to stay abreast of emerging science and technology (S&T) around the world, to leverage others' investments, and to seek out collaborations in areas where researchers need to remain at the leading edge.

Today, the globalization of science and technology has profoundly impacted the global research landscape and the ways in which the international research community accesses, participates in the production of, and exchanges scientific knowledge. International knowledge exchanges can occur through a number of mechanisms, such as science conferences and professional meetings, researcher seminars and visits, the scientific literature, and joint research projects. In addition to curiosity-driven (typically academic) engagement, international research collaboration can play a critical role in ameliorating global challenges, such as natural and engineered disasters (e.g., Fukushima Daiichi nuclear disaster) and pandemic disease outbreaks (e.g., H1N1). Despite these opportunities, however, there is often a cultural and political reluctance in the United States, driven partly by intellectual property and economic concerns, to international collaboration in science and technology, particularly in the defense research space.

The United States has, however, historically collaborated with its allies to develop the technologies needed for defense, such as radar, submarines, protective clothing, and medicines. For example, since the Second World War, U.S. defense researchers have worked closely with those from the other "five eyes" (United Kingdom, Canada, Australia, and New Zealand) under The Technical Cooperation Program (TTCP). Other technology engagement activities include the North Atlantic Treaty Organization Science and Technology Organization

[1]2014 Global R&D Funding Forecast. R&D Magazine and Battelle. December 2013. www.rdmag.com.

[2]"Globalization of S&T: Key Challenges Facing DOD." Timothy Coffey and Steven Ramberg. Center for Technology and National Security Policy: National Defense University. February 2012, .p. 29.

(NATO STO) and scientist and engineer (S&E) exchanges amongst defense allies at their laboratories and research centers. In addition, the Services maintain an overseas presence to monitor the development of technologies of interest and to prevent "technological surprise," a military advantage gained by another country by leapfrogging U.S. capability.

The two activities, collaboration and monitoring, can in principle reinforce each other: monitoring activities can locate opportunities for collaboration and collaborators can also monitor while they work. The globalization of research has affected both of these activities as research and development capabilities grow worldwide and research collaboration across countries rises. Research and development are still heavily national activities, but much less so than in the past as the R&D world becomes flatter and more networked. Under these conditions, a military strategy that depends on huge gaps in technological capability cannot be maintained. Security under globalization needs to depend not only on technological dominance but also on cooperative relationships.

This shift has important implications for the way the U.S. DoD engages internationally in science and technology. Monitoring is still important, but is now aided importantly by a variety of information technologies and tools. This report argues that DoD should develop a department-wide strategy to maintain global awareness and to identify opportunities to leverage its R&D investments and collaborate internationally.

Each of the DoD's Services (Army, Air Force, and Navy—including the Marines) has research enterprises with varying institutional configurations in its international S&T engagement activities. In addition to maintaining overseas S&T offices, each Service has S&Es at military laboratories and at universities (including DoD-funded university investigators) who also engage with international contacts and collaborate in joint international research. DoD enterprise-wide global awareness begins with ensuring that this S&T workforce is globally aware of emerging S&T developments. However, researchers at defense laboratories and research centers who wish to engage internationally face funding limitations and restrictions on travel and conference participation, as well as security walls closing in on research activities that should be as open as possible within the boundaries of national security concerns. These barriers limit the DoD S&T workforce's ability to maintain global awareness and to develop necessary collaborations. It will also hamper the Department's ability to recruit and retain top S&E talent. Awareness via publications and data analytics is useful, but only provides a partial (and oftentimes delayed) picture of global S&T and cannot replace in-person S&T engagement. Thus, the Services' S&T field offices provide an important and unique opportunity for on-the-ground engagement and relationship and network building. Fully taking advantage of this opportunity, however, hinges on the ability of DoD to relay this information throughout its network of S&Es and decision makers.

While the DoD currently has a variety of mechanisms in place for global S&T awareness and collaboration, those mechanisms are not integrated well, barriers and impediments to successful implementation exist, and outcomes are

not measured systematically to assess effectiveness. International S&T engagement activities are done on an ad hoc basis, and information gained either through monitoring or collaboration is not integrated effectively into overall situational awareness, either horizontally across the Services S&T enterprises or vertically to the Office of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) to effectively provide input for strategic S&T decision making.

The committee did not identify a single "best" approach for maintaining global awareness, but rather believes an integrated suite of methodologies is needed. Enterprise-wide global S&T awareness benefits researchers, administrators and policy makers in academia, industry, and government both in the United States and overseas. Further, many of the mechanisms employed by the DoD, such as S&E exchanges and conference support, are also used by other S&T organizations around the world. Thus, the DoD should identify opportunities to leverage these efforts. If the DoD does not develop a specific, clearly defined and implementable enterprise-wide strategy for fully taking advantage of global S&T, either by absorbing knowledge and talent from the international research community or collaborating, it runs the risk of losing technological competency with severe implications for economic and national security.

The committee offers the following four recommendations and important first steps to implement each:

Recommendation I

The ASD/R&E should develop a specific, clearly defined and implementable strategy to maintain global awareness of relevant scientific and technological advances that emerge from the dynamic, interconnected, and expanding global S&T enterprise.

Important first steps include:

- **The ASD/R&E, in concert with the R&E Executive Committee (ExCom) and the S&T ExCom, should adopt as an operating principle the use of global technology awareness to inform S&T-related investments across the Defense Research Enterprise (DRE).**
- **The ASD/R&E should, within the Reliance 21 framework, require each Community of Interest to identify and assess (with periodic updates) relevant global research results; those assessments should inform portfolio reviews as well as programmatic investments.**
- **The head of the research enterprise for each of the Services should ensure that Service-specific S&T investment strategies**

are similarly informed by awareness of related international research.
- **The heads of the research enterprises for the Services should work collaboratively to develop a regional S&T engagement strategy, together with clearly defined outcomes and measures, to focus the activities of overseas field offices.**

Recommendation II

As "champions" for the S&T workforce,[3] the S&T Executive Committee should establish a workforce development strategy to build and maintain global awareness.

Important first steps include:

- **The ASD/R&E, in concert with the S&T ExCom, should drive a culture across the Defense Research Enterprise that values external ideas and capabilities by consistently communicating and reinforcing the importance of global awareness and engagement.**
- **The ASD/R&E, in concert with the S&T ExCom, should require each Community of Interest (COI) to share its assessment of relevant global research results with the entire Defense Research Enterprise, and to provide DRE researchers an opportunity to contribute to ongoing assessment efforts.**

Recommendation III

DoD and its Services should conduct a systematic review and analysis of existing mechanisms intended to improve global S&T awareness to identify steps to remove barriers and improve their effectiveness.

Important first steps include:
- **The ASD/R&E, in concert with the R&E ExCom, should establish policy and provide support to enable DRE researchers to attend relevant technical conferences and workshops.**
- **The heads of the research enterprises for the Services should work cooperatively to staff field offices with the scientific, linguistic, and cultural expertise needed to effectively implement their collective regional S&T engagement strategy.**

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[3] Reliance 21. Operating Principles: Bringing Together the DoD Science and Technology Enterprise. January 2014. P. 4.

- **In each of the major overseas field offices, the Service leads should work collaboratively to develop and implement a local inter-agency engagement strategy in order to leverage the presence of other US government agencies.**
- **The ASD/R&E should work with the heads of the research enterprises for the Services to establish DRE-channel reporting in parallel to existing Service-specific reporting from the overseas field offices.**

Recommendation IV

The DoD and its Services should develop an enterprise-wide solution to implement the strategy called for in Recommendation I.

Important first steps include:

- **The ASD/R&E should establish DRE-wide reporting protocols and a DRE-wide searchable repository to begin building global situational awareness. (The committee notes that the R&E Gateway hosted by the Defense Technical Information Center (DTIC) may be useful in this regard.) Topics to be considered include:**
    - **What are the S&T priorities for international reporting?**
    - **Is reporting focused on engagement, collaboration, and/or technology assessments?**
    - **How often and in what format should reporting occur?**
    - **Who should be able to access field S&T assessments?**
    - **What are metrics for successful reporting?**
- **The ASD/R&E should establish a DRE-wide platform to support bibliometrics and other related analytics; a critical enabler is enterprise-wide access to appropriate bibliographic data sets.**

1

Globalization of Science and Technology

"There is no national science just as there is no national multiplication table."[1]
Anton Chekhov (1860-1904)

While globalization of science is by no means a new phenomenon, the 21st century science and technology (S&T) enterprise is more geographically distributed, more interconnected, and more dynamic than ever before. Advances in science and technology fueled the pace of globalization throughout the 20th century; now globalization is accelerating the pace of advances in S&T. Long-standing research investment strategies are giving way to more collaborative models as institutions of all kinds seek to leverage a globally distributed talent base. The physical borders that define national sovereignty pose minimal barriers to the flow of information and ideas and do little to impede the coalescence of global networks among researchers or the expansion of global technical innovation by industry. The 20th century birth of the Internet spawned what Yale researchers termed "a speeded-up virtuous cycle" in which "the internet and electronic publication revolution have proved a boon—expanding the areas of research and accelerating the pace of knowledge exchange."[2]

A recent report published by the European Commission observed that "[o]ver the past few decades the international landscape has changed in ways that seem both dramatic and contradictory. New players have emerged, notably emerging economies such as China, Brazil, India, and South Africa. Smaller economies like Vietnam are to a greater degree imitating the Chinese strategy of placing science, technology and innovation (STI) at the centre of the economic development strategies, and raw materials based economies like Australia are increasingly STI-driven. Although Europe, Japan and North America still dominate aggregate STI investment globally, their shares are declining, and the international landscape is increasingly multi-polar."[3]

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[1]Note-Book of Anton Chekhov. NY: B.W. Huebsch, Inc. 1921, p. 18.

[2]"Globalization and Science: A Speeded-Up Virtuous Cycle," Ramamurti Shankar. *YaleGlobal*, March 28, 2003.

[3]"International Cooperation in Science, Technology and Innovation: Strategies for a Changing World." Report of the Expert Group established to support the further devel-

This reality, corroborated by statistical indicators, has broad implications for the U.S. Department of Defense (DoD) as well as the U.S. government more broadly. This chapter describes the changing global science and technology enterprise, discusses a range of mechanisms for assessing and engaging that enterprise, and highlights key implications for the DoD.

1.1 Painting the S&T Landscape

Organizations whose missions depend on utilization of cutting-edge S&T must maintain awareness not only of the global S&T landscape as it exists today but also of the drivers that are reshaping that landscape. Statistical indicators, e.g. a nation's R&D spending, provides a snapshot of the landscape but are not necessarily useful in forecasting how the landscape will change over time. Trend analysis is more helpful in this regard but is of minimal value in anticipating nonlinearities induced by important drivers of S&T globalization.

The National Commission for the Review of the Research and Development Programs of the United States Intelligence Community observed that "[f]oreign: "Foreign governments are developing policies to foster technological innovation as a key mechanism for stimulating sustainable economic growth and enhancing security—the fruits of which will present both challenges to and opportunities for U.S. interests. The globalization of R&D [research and development] capabilities is becoming an increasingly important component of the business strategies of multinational corporations, not only because they wish to boost competitiveness by enhancing local customization, gaining access to new markets, and placing technical staff close to manufacturing and design centers, but also because the accelerating pace of S&T-based innovation and its potential for high-margin products drive successful firms to seek out the best S&T talent, regardless of where it resides."[4]

The European Commission has identified a number of factors that drive the globalization of science, including:

- "The globalisation of the world economy drives firms to increasingly access scientific sources outside their local boundaries.
- Students and researchers are increasingly mobile. As a consequence, scientific institutions and firms are ever more competing for talent in a global labour market.
- The ICT [information and communications technology] and the Internet revolution have reduced the cost of international communication and boosted international exchange in science. These trends are am-

opment of an EU international STI cooperation strategy. ISBN 978-92-79-26411-5. Copyright European Union 2012, p. 9.

[4]Report of the National Commission for the Review of the Research and Development Programs of the United States Intelligence Community; Unclassified Version. 2013, p. 7 .

plified by the growth in transport systems and reductions in real transport costs of the last few decades.

- ICT and internet have also fostered new ways of gathering knowledge, leading to innovative international knowledge transfer models in the fields of fundamental research.
- The research agenda is increasingly being made up of issues that have a global dimension, such as climate change, energy, safety, pandemics.
- Policy makers are increasingly focusing attention on international S&T cooperation and funding programmes to stimulate internationalisation of higher education and research. This includes many governments from emerging economies, who have come to view Science and Technology (S&T) as integral to economic growth and development. To that end, they have taken steps to develop their S&T infrastructures and expand their higher education systems. This has brought a great expansion of the world's S&T activities and a shift toward developing Asia, where most of the rapid growth has occurred.
- Costs of and access to infrastructure lead to stronger incentives to cooperate and share resources across boundaries.
- Increased specialisation of knowledge production globally makes excellence being located more diversely and makes it vital to seek advanced knowledge where it is.
- Scientific knowledge is produced with greater "speed" and impact, creating incentives to avoid duplication."[5]

Although the effects of these drivers can be observed in statistical trends, it is difficult to directly correlate cause and effect; it is even more difficult to project how these and other drivers will reshape the global landscape over the coming decades. The charts that follow provide a sampling of leading and lagging indicators that describe the global S&T landscape from differing perspectives.

The Science and Engineering (S&E) Indicators report published biennially by the National Science Board (NSB) draws from U.S. and international data to provides a snapshot of the scope, quality, and vitality of the science and engineering enterprise. Global R&D expenditures are an important leading indicator of a nation's commitment to technology-based innovation. While overall R&D execution continues to be concentrated in three regions of the world (Figure 1-1a), relative shares are shifting due to substantial growth in Asia. In fact, while aggregate R&D spending grew at an estimated 6.7 percent over the 10-year period between 2001 and 2011, China was the largest single contributor to the

[5]"International Cooperation in Science, Technology and Innovation: Strategies for a Changing World." Report of the Expert Group established to support the further development of an EU international STI cooperation strategy. ISBN 978-92-79-26411-5. Copyright European Union 2012, pp. 21-22.

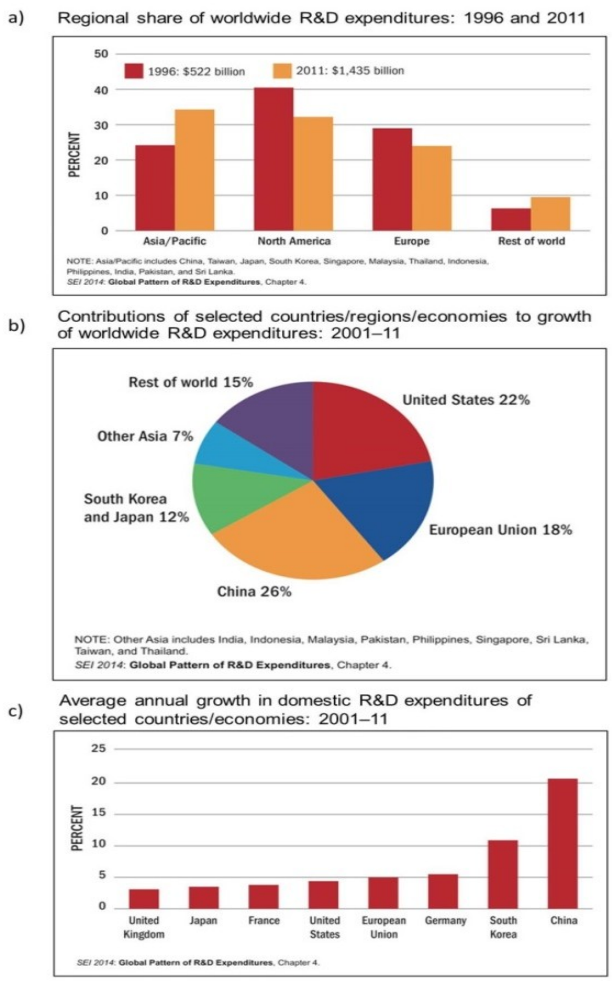

FIGURE 1-1 NSF Science and Engineering Indicators showing (a) 1996–2011 regional shares of worldwide R&D expenditures, (b) 2001–2011 contributions of selected countries/regions/economies to growth of worldwide R&D expenditures, and (c) 2001–2011 average annual growth in R&D expenditures of selected countries/economies. SOURCE: National Science Board. Science & Engineering Indicators 2014 Digest. Retrieved online on April 4, 2014 from http://www.nsf.gov/statistics/seind14/index.cfm/digest/.

Growth in R&D expenditures, with Asia collectively contributing 45 percent to overall growth (Figure 1-1b). [6] While the United States, European Union, and Japan continue to dominate in aggregate annual R&D expenditures, China

[6]Science and Engineering Indicators 2014. National Science Board. 2014. Arlington VA: National Science Foundation (NSB 14-01), pp. 4-17.

has shown tremendous growth in R&D investment between 2001 and 2011—almost two times that of South Korea and nearly five times that of the United States (Figure 1-1c).

While aggregate R&D spending is a useful indicator of a country's commitment to innovation, it is only one of many parameters needed to assess the relative strengths and weaknesses of a nation's S&T enterprise. Equally important, for example, are measures that derive from a nation's ability to effectively execute their research investment, for example by measuring workforce capacity. Figure 1-2a provides one measure of S&E workforce capacity by examining the growth in S&E first university degree awards (i.e., completion of a terminal undergraduate degree program) between 2000 and 2010 for selected countries. During this time period, the aggregate number of S&E first university degrees awarded in China grew by an estimated 259 percent with the largest growth in the number of degrees awarded in physical and biological sciences (approximately 447 percent) and engineering (approximately 282 percent). During this same period, aggregate S&E degrees awarded in the U.S. grew by 32 percent, with the largest growth in social and behavioral sciences (approximately 39 percent) followed by physical and biological sciences (approximately 35 percent) and engineering (approximately 25 percent).[7]

A related measure of a nation's R&D capacity (and potentially an indication of a nation's R&D investment strategy), is the growth and scientific domain-concentration of S&E doctoral degrees awarded. Figure 1-2b shows the ratio of doctoral degrees awarded in 2010 by field of study for selected countries. More than half of the 2010 S&E doctoral degrees awarded in China, Japan, South Korea, and Taiwan were in engineering (compared with the United States and United Kingdom, where only about one quarter of the doctoral degrees were in engineering.[8] On the other hand, the United States and many European countries produce larger percentages of doctorates in physical and biological sciences; disciplines that often provide foundational knowledge and discoveries that lead to technological advances

Research universities are essential to a vibrant national R&D enterprise. Figure 1-3 examines data compiled from the Times Higher Education World University Rankings 2013-2014, which used 13 indicators across four core missions: teaching, research, knowledge transfer, and international outlook to generate the rankings.[9] While North America and Europe still dominate most higher education rankings (Figure 1-3a), other regions are breaking into the Top 100, particularly in engineering and technology (Figure 1-3b). For example, 16 countries are represented in the overall Top 100 rankings list, whereas 24 countries have one or more universities ranked among the Top 100 in engineering and

[7] Ibid. Appendix table 2-37.

[8] Ibid. Appendix tables 2-41 and 2-42. Note: Data not available for degrees awarded in mathematical or computer sciences in Russia, China, and Japan.

[9] Times Higher Education World University Rankings. Retrieved online March 27, 2014 from http://www.timeshighereducation.co.uk/world-university-rankings/2013-2014/.

technology. While the United States dominates both lists, its share is smaller and the geographic distribution is greater for top-ranked universities in engineering & technology. While many have not yet broken into the overall Top 100 rankings, the BRIC countries (Brazil, Russia, India, and China) and other emerging economies are intent on strengthening their higher education institutions. Within this cohort, Asia dominates the Top 100, but the geographic distribution spans the globe (Figure 1-3c).

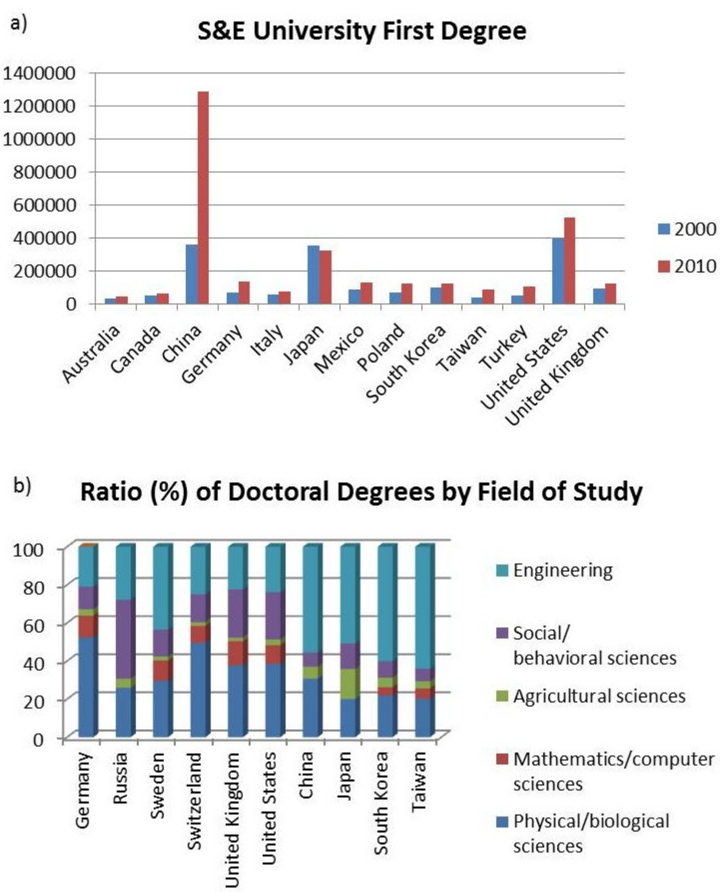

FIGURE 1-2 National Science Board Science and Engineering Indicator data that examines (a) S&E first university degrees for selected countries between 2000 and 2010 and (b) S&E doctoral degrees by field of study for selected countries in 2010. SOURCE: Data compiled from National Science Board. 2014. Science and Engineering Indicators 2014. Appendix Tables 2-37, 2-41, and 2-42 (data not available for degrees awarded in mathematical/computer sciences in Russia, China, and Japan).

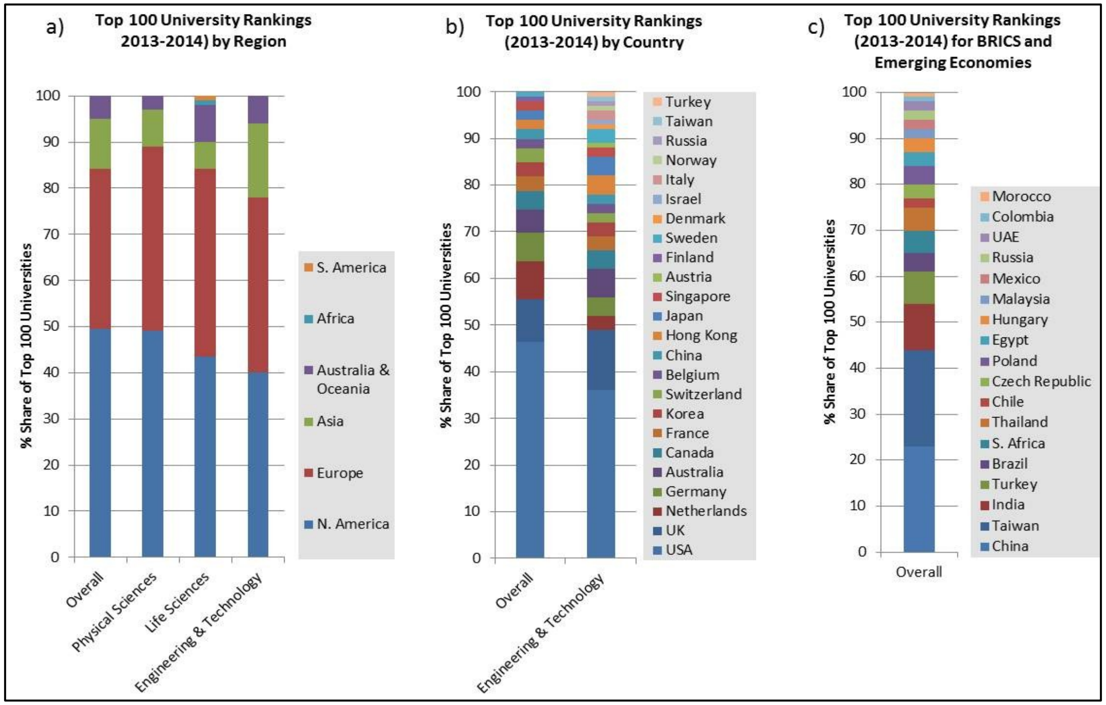

FIGURE 1-3 Top 100 (2013–2014) University Rankings (a) by region, overall and domain-specific; (b) by country, overall and engineering and technology; and (c) for BRIC countries and emerging economies, overall. SOURCE: Data compiled from Times Higher Education World University Rankings. Retrieved online March 27, 2014 from http://www.timeshighereducation.co.uk/world-university-rankings/2013-2014/.

In "The rise of research networks," Jonathan Adams argues that "New collaboration patterns are changing the global balance of science. Established superpowers need to keep up or be left behind." He acknowledges that "the established science superpowers of the United States and Europe have dominated the research world since 1945" but asserts "this Atlantic axis is unlikely to be the main focus of research by 2045, or perhaps even by 2020."[10] Cross-border collaborations are occurring at all levels, from the fluid peer-to-peer networks among individual researchers to more structured institutional relationships to multi-national agreements to jointly invest in pursuit of a shared goal. The outputs from such collaborations are often equally borderless—confounding efforts to attribute scientific leadership to a specific nation, institution, or individual.

Scientific collaboration is growing at multiple levels across every field, as evidenced by lagging indicators such as coauthorship of publications. According to the S&E Indicators 2014, "collaboration on S&E research publications over the last 15 years has been increasing, with higher shares of scientific articles with more than one named author and a higher proportion of articles with institutional and international coauthorships. The largest increase was in international collaboration; the percentage of articles with authors from different countries rose from 16 percent to 25 percent between 1997 and 2012."[11] While international collaboration expanded in every field between 1997 and 2012, it grew unevenly. Astronomy leads in international collaboration; in 2012 approximately 56 percent of its articles were internationally coauthored. Other fields with relatively high rates (27 percent to 34 percent) of international collaboration include geosciences, computer sciences, mathematics, physics, and biological sciences (the rate of international collaboration was lower for agricultural sciences, medical sciences, engineering, psychology, chemistry, social sciences, and other life sciences, which was the lowest at only 17 percent).[12]

International collaboration rates also vary by country. Figure 1-4 shows the percentage of S&E articles with international co-authorship for nations that have universities in the Times Higher Education overall Top 100 rankings (see Figure 1-3b).[13] From an aggregate perspective, approximately 25 percent of the S&E articles published in 2012 had international co-authorship; every nation with top-ranked universities exceeded that ratio. While U.S. researchers collaborate at a lower rate than researchers in Europe, Singapore, Canada, and Australia, 36 perecent of US S&E articles are internationally coauthored. In 2012, collaboration with China accounted for 16.2 percent of U.S. internationally coauthored articles, an expansion from only 5.1 percent in 2002. Other major

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[10]The rise of research networks. Jonathan Adams. *Nature* Volume 490. October 2012.

[11]Science and Engineering Indicators 2014. National Science Board. 2014. Arlington VA: National Science Foundation (NSB 14-01), pp. 5-40-41.

[12]Ibid.

[13]Ibid. Appendix Table 5-41. Note: Countries with less than 1percent of internationally coauthored articles in 2012 are omitted, so Hong Kong is not included in the chart.

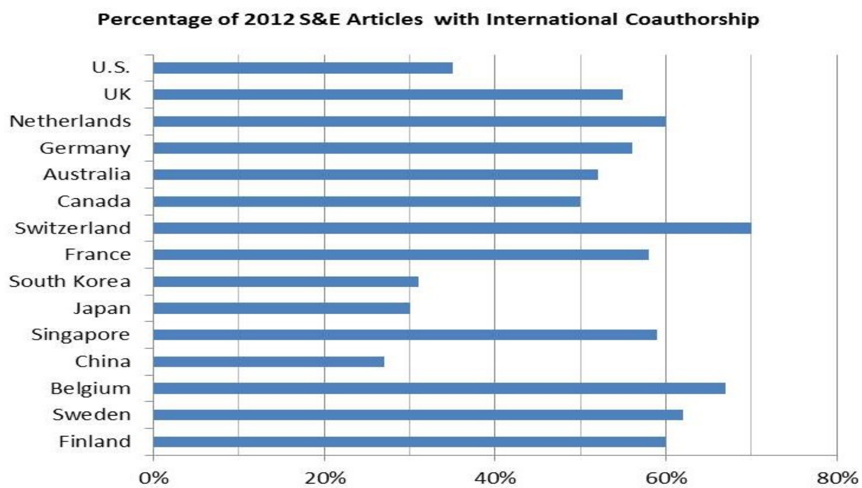

FIGURE 1-4 Percentage of S&E articles with international co-authorship in 2012 for countries with overall top 100-ranked universities. SOURCE: Data compiled from Appendix Table 5-41 of National Science Board Science and Engineering Indicators 2014. Arlington VA: National Science Foundation (NSB 14-01).

collaborators in 2012 included the United Kingdom (14.3 percent), Germany (13.3 percent), and Canada (11.4 percent).[14] Figure1-5 shows the percentage share of U.S. international S&E articles in 2012 for countries with universities in the Times Higher Education Engineering and Technology Top 100 rankings (see Figure 1-3b).

As the fruits of basic research mature into applications, a competitive dynamic often emerges as nations, institutions, and individuals seek to be recognized as "the best." The global S&T landscape morphs as national and regional leadership positions shift. This dynamic is well documented by the TOP500 Project which benchmarks supercomputer performance (speed) around the world and maintains statistics dating back to 1993. While the United States held the lead for many years, the top-ranking site has shifted across national borders four times between June 2010 and June 2013 (Figure 1-6). In many other technology areas, which lack quantitative benchmarks against which performance can be measured, it is far more difficult to identify who is the best at a given point in time.

A variety of other leading and lagging indicators appear in the biennial publication of the *Science and Engineering Indicators*. The collective array, even when supplemented by analyses produced by other sources, provides an inadequate picture of the global S&T landscape. Institutions and governments around the world are struggling to better understand—and more efficiently lev-

[14]Ibid. Appendix Table 5-56.

erage—the global S&T enterprise. A recent Thomson Reuters report observed that "[t]he global research landscape of the past decade has become so dynamic as to be described in terms of tectonic movements, most importantly for that of China. Continents—and countries—once distant from one another both physically and metaphorically are now appearing side-by-side and still new landforms are emerging. In another decade, the geography of science is sure to be very different from that of today."[15]

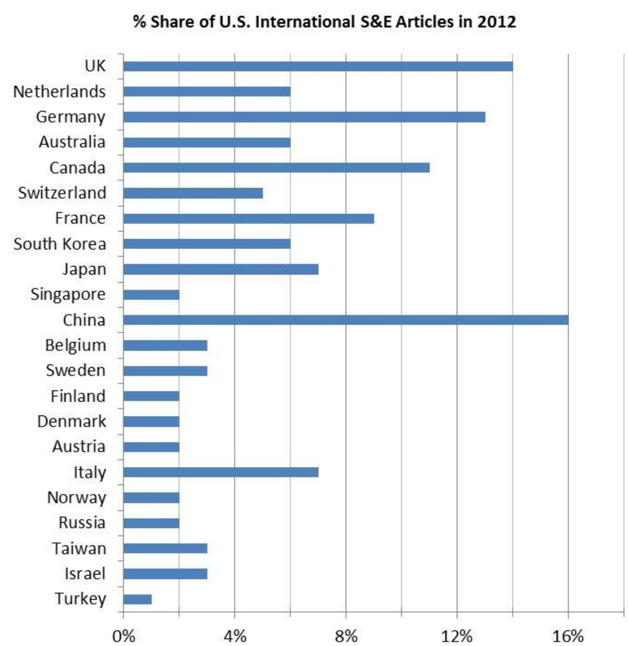

FIGURE 1-5 Percentage share of U.S. international S&E articles in 2012 for countries with top 100-ranked universities in engineering and technology. SOURCE: Data compiled from Appendix Table 5-56 of National Science Board Science and Engineering Indicators 2014. Arlington VA: National Science Foundation (NSB 14-01).

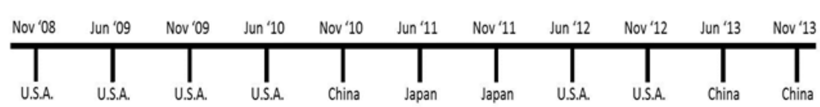

FIGURE 1-6 Top-ranked supercomputer sites; each time point shows the site location (country) of the world's number one performing computer system. SOURCE: Data compiled from "Top500 Lists." Retrieved March 27, 2014 from www.top500.org/lists/.

[15]The Research & Innovation Performance of the G20. September 2013. Copyright 2013 Thomson Reuters, p. 5.

1.2. Global S&T Engagement

According to a recent National Research Council study, "the increased access to information has transformed the 1950s paradigm of 'control and isolation' of information for innovation control into the current one of 'engagement and partnerships' between innovators for innovation creation. Current and future strategies for S&T development need to be considered in light of these new realities."[16] Such a world, in which science and technology capabilities are spreading steadily, provides both opportunities and challenges for global S&T engagement.

Global health research, for example, holds more promise of reducing disease burdens in an era when many countries can contribute and the historically dominant efforts of the U.S. National Institutes of Health are joined by the contributions of many strong partners. The demand for more productive agriculture, particularly in developing countries, as land available for crops shrinks and environmental stresses increase, likewise becomes an opportunity for global cooperation and progress. At the same time and through the same developments, however, competition can become more acute. Pharmaceutical firms and exporters of agricultural products may not find their more populated commercial landscapes to be easy places in which to survive or thrive. Disruptive technologies can shift the economic balance rapidly; as S&T capability grows around the world, it becomes harder to predict where and when a commercially disruptive technology is most likely to be developed.

In such a landscape, all S&T-based organizations benefit from wider global engagement. Where the organization's mission is providing a global public good—such as improved health, cleaner energy, or a more secure food supply—cooperation across borders builds the common knowledge base and brings more human resources to bear on the issue. Further, a partner country that deploys its own scientists and engineers to tackle global challenges is more likely to benefit at the national and local level downstream as solutions are implemented. The eradication of smallpox, for example, while led by the U.S. Centers for Disease Control, could never have been successful without significant local capabilities in all the countries where the remnants of the disease existed. Geography is also an important consideration in global S&T engagement as one country cannot do all global oceanography research, all Arctic research, or all disease vector research. Competing organizations also have a need to reach out globally in order to have full access to growing external knowledge in their technology areas and to maintain sufficient in-house skills and understanding to either introduce new technologies, catch up, or very quickly adjust if critical technologies are developed or introduced elsewhere first. So, for example, U.S. firms that want to compete in the world market for clean energy technologies cannot build their capacity to compete by being isolated. Rather, they need to be an active member

[16] *S&T Strategies of Six Countries: Implications for the United States*. National Research Council. Washington, DC: The National Academies Press, 2010, p. 1.

of the international S&T community, sharing and learning from the relevant research communities, tracking what other firms are doing, and getting to know the needs and constraints of their potential markets.

A recent report by the European Commission delineated a scale of coordination: from Competition (overlapping programs in competition with no coordination) to Co-ordination (information exchange on distributed programs) to Co-operation (distributed but linked programs, shared access, strategic divergence and specialization) to Collaboration (pooled programs with merged management) to Integration (joint strategic approach, program with full coordination). The report also argued the "need to strive for moving upwards on this scale to achieve a more collaborative and integrated strategy for international cooperation."[17]

Mechanisms for awareness and engagement in science- and technology-intensive areas also form a continuum from more passive to more active (Table 1-1 illustrates this range). For example, data analytics and bibliometric analyses require little to no in-person engagement. While these mechanisms can generate overviews of research fields and indicate outstanding research, the indicators being measured, such as publications and patents, often lag behind the cutting edge of research. In the case of other information, such as conference participation, unreviewed online reports, etc., the quantity of available data to mine is voluminous. Nevertheless, these mechanisms are increasingly important and enabling given the sheer volume and variety of available information and the need to effectively allocate scarce human resources by targeting their analytic efforts.

The use of statistical analyses of patents and publications as a means to better understand what is happening globally is not new. The NSB Science and Engineering Indicators previously discussed are a rich source of such measures. The Royal Society has also made use of bibliometrics to analyze how collaborative networks were changing regionally and globally.[18] A recent report by Thomson Reuters also used bibliometric data to analyze the scholarly output and innovation capacity of the G20[19] in an effort to provide insight on questions including: "…which regions are leading and in what areas? Which countries are falling behind? Where are there emerging pockets or growth? What is in decline? What technology areas dominate?" While useful, such measures are still lagging indicators and rely on robust access to large data assets.

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[17]International Cooperation in Science, Technology and Innovation: Strategies for a Changing World. Report of the Expert Group established to support the further development of an EU international STI cooperation strategy. ISBN 978-92-79-26411-5. Copyright European Union, 2012.

[18]Knowledge, Networks and Nations: Global scientific collaboration in the 21st century. ISBN 978-0-85403-890-9. Copyright The Royal Society, 2011.

[19]The Research & Innovation Performance of the G20. Thomson Reuters. September 2013, p. 3. [Note: The G20 includes Argentina, Australia, Brazil, Canada, China, European Union, France, Germany, Great Britain, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, and United States of America.]

TABLE 1-1 Mechanisms for S&T Awareness and Engagement

	Mechanism	Description	Objective	Measure of Success	Challenges	Strengths
Passive	Data analytics and Horizon Scanning	Watching the literature; analyzing trends	Generate overview; map the average to recognize the outstanding	New insights generated. Has this information changed what we did in the last year? How and how often?	Open literature lags behind the research process	Unobtrusive; gathers information across a wide range of places
	Reading	Reading the literature	Learn technical content	Are researchers more up to date as a result of this activity? (Are researchers citing most recent findings?)	Quantity is often voluminous	Good technical detail available
	Professional meetings	Attending meetings organized by professional societies	Access to the newest results; identify future leaders	Has the information gathered at meetings changed what was done in the last year? How and how often?	Relevant new results are scattered among meetings	Fresh results; informal interaction is possible
	Workshops	Organizing workshops around particular topics of interest	Fresh results in targeted areas	Has the information gathered at workshops changed what was done in the last year? How and how often? Are researchers more up-to-date as a result of this activity?	Funding and logistics; getting the right people there	Concentrated collection of relevant research; much opportunity for informal interaction
	Personal contact	Visiting laboratories or other research sites, exchange of personnel	Access to the newest results	Are researchers more up-to-date as a result of this activity? Are new insights reported? Have the new insights changed what is being done?	Finding the best laboratories to visit	Visual access to research process; can talk to more people about the work
	Collaboration	Designing, carrying out, and analyzing research together	Create new knowledge; combine skills	Were we able to do things we could not have done on our own? Have we opened wider our window on developments in an important research area?	Hard to keep knowledge private when competition is involved	Deep understanding for both partners; cost efficiency
Active	Project funding	Funding, managing, and/or actively collaborating in research projects	Develop specific new knowledge	Did the project contribute to a growing research area of interest to the organization? Has there been appropriate follow-up engagement in that area? Did seed grant create relationships that were helpful in engagement in the area?	Technical mastery is hard for program managers to achieve/maintain when not working in the laboratory	Best people can be chosen; can fill knowledge gaps

SOURCE: Committee generated.

Work by Nesta[20] in the United Kingdom also illustrates the growing interest in the topic of technology forecasting and examines an array of quantitative techniques used in Future-oriented Technology Analysis.[21] A follow-on paper analyzes these quantitative techniques in the context of a more general analytic framework to illustrate "the implicit assumptions about the uncertainty, ambiguity and ignorance that distinct quantitative techniques make when exploring the future." [22] The authors observed that "Monitoring methods (such as raw bibliometrics or web-scraping) may be able to identify potential outcomes and be useful for activities such as horizon-scanning, but they have limited analytical potential on their own to inform on future states of the world. Therefore, their usefulness depends on their implementation within a larger foresight methodology."[23]

A National Research Council report also examined a diverse array of existing forecasting methods and processes, noting that "[t]he value of technology forecasting lies not in its ability to accurately predict the future but rather in its potential to minimize surprises."[24] The report also sets forth a set of attributes for an "ideal forecasting system"[25] which integrates both multiple data sources and multiple forecasting methods and processes. Of note, the recommended system makes use of both quantitative and qualitative data and includes both "big data" analysis and diverse human participation.

More active mechanisms for engagement and awareness include participation in professional meetings and conferences, which bring together large concentrations of junior and senior researchers and allow for informal information exchange, as well as access to the newest research findings. Workshops are also a venue for information exchange, typically bringing together researchers around more focused topics of interest. However, given the vast number of meetings held each year and limited travel budgets, especially for international travel, researchers must take a strategic approach to which scientific fora they will participate in.

The most active mechanisms for engagement and awareness include personal contact (e.g., laboratory and other site visits, personnel exchanges), research cooperation and collaboration, and providing funding for research projects. These mechanisms allow for more formal information exchange and

[20]Nesta is a UK independent charity that works to increase innovation capacity (formerly NESTA, National Endowment for Science, Technology and the Arts http://www.nesta.org.uk/about-us/our-history

[21]Quantitative Analysis of Technology Futures. Part I: Techniques, Contexts, and Organizations. Nesta Working Paper No. 13/08. T. Ciarli, A. Coad, and I. Rafols.

[22]Quantitative Analysis of Technology Futures. Part 2: Conceptual framework for positioning FTA techniques in policy appraisal. Nesta Working Paper No. 13/09. T. Ciarli, A. Coad, and I. Rafols.

[23]Ibid. p. 29.

[24]Persistent Forecasting of Technologies. National Research Council. Washington, DC: The National Academies Press. 2009, p. 1.

[25]Ibid. Table 7-1.

provide opportunities to share, and thereby reduce costs and risks, as well as leverage the best available talent, research capabilities, and infrastructure. Such high degrees of research engagement and collaboration require explicit and detailed agreements about research objectives and roles, intellectual property, and fully consider all political and national security sensitivities.

Each of these mechanisms has a different set of objectives, strengths, and challenges that should be considered when determining how to best engage with the international research community. As technologies become more sophisticated, organizations will need to employ increasingly active mechanisms to remain capable of innovating, following quickly on the innovations of others, and absorbing the benefits of innovation wherever it happens. In some cases, specific technology areas or one's choice of desired research collaborator—whether an individual, organization, or country—can limit or restrict available engagement mechanisms. Regardless of which mechanisms are used, there should be clearly articulated success metrics to gauge effectiveness and to improve future engagement efforts. Table1-1 provides potential examples of how an organization might measure success.

While a U.S. research field must engage bottom-up, from the initiatives of investigators, a technology-intensive organization such as the DoD needs to take a more deliberate approach.

1.3 Implications for the Department of Defense

"*The United States has long relied on technically superior equipment and systems to counter adversaries. . . However, this superiority is being challenged by increasingly capable and economically strong potential adversaries that are likely developing and fielding counters to some or all of the key technologies on which the United States has come to rely*."[26]

The DoD has long relied on technological superiority to maintain military advantage and has successfully leveraged U.S. leadership across a diverse spectrum of scientific and technological domains. At the same time, the U.S. defense establishment has for decades benefitted from foreign scientific and engineering developments, for example:[27]

- Enrico Fermi, an Italian physicist who received the Nobel Prize in 1938 for "his discovery of new radioactive elements produced by neutron irradiation, and for the discovery of nuclear reactions brought about by slow neutrons."
- Heinrich Hertz, a German physicist who was the first to demonstrate experimentally the production and detection of Maxwell's waves.

[26]Quadrennial Defense Review 2014. U.S. Department of Defense, p. 25.
[27]Available at www.inventors.about.com; www.nobelprize.org.

- Sir Robert Alexander Watson-Watt, a Scottish physicist who developed the radar locating of aircraft in England.
- Christian Andreas Doppler, an Austrian physicist who first described how the observed frequency of light and sound waves was affected by the relative motion of the source and the detector (the Doppler effect).
- Tim Berners-Lee, an English physicist credited with leading the development of the World Wide Web.
- Charles K. Kao, a Chinese physicist who won the 2009 Nobel Prize in Physics "for groundbreaking achievements concerning the transmission of light in fibers for optical communication."
- Andre Geim and Konstantin Novoselov, who both originally studied and began their careers as physicists in Russia and won the 2010 Nobel Prize in Physics "for groundbreaking experiments regarding the two-dimensional material graphene" conducted at the University of Manchester, United Kingdom.

The DoD's 2014 Quadrennial Defense Review (QDR) Report acknowledges that "[w]hile the global technology landscape indicates that the United States should not plan to rely on unquestioned technical leadership in all fields, the Department must ensure that technological superiority is maintained in areas most critical to meeting current and future military challenges."[28] Three overarching characteristics of the global S&T landscape—ongoing geographic expansion, growing interconnectedness, and shifting centers of S&T leadership—combine to make the DoD's ability to sustain technological superiority to underpin military advantage a daunting challenge. The authors of "Globalization of S&T: Key Challenges Facing DOD" concluded that "[m]aintaining an authoritative awareness of S&T around the world will be essential if the United States is to remain economically and militarily competitive."[29] The dual challenge of maintaining technological superiority in critical areas and also remaining globally aware of relevant S&T advances is not new, but the nature of that challenge is changing.

Quantitative measures such as R&D spending trends provide useful indicators of how the S&T landscape may evolve in a general sense, but they yield little insight as to the dynamics within specific research domains that are of critical importance to the DoD. U.S. domination in total R&D spending is far less relevant than its relative position within research domains that underpin military capabilities.

Lagging indicators, including publications and patents, further corroborate the dynamic and interconnected nature of the global S&T landscape and are commonly used to provide more granular assessments of cutting-edge research.

[28] Quadrennial Defense Review 2014. U.S. Department of Defense, p. 25.

[29] "Globalization of S&T: Key Challenges Facing DOD." Timothy Coffey and Steve Ramberg. Center for Technology and National Security Policy: National Defense University. February 2012, p.. 29.

But, as observed in a report by the Royal Society, they are "incomplete proxies for scientific output and scientific translation, the first being predominantly the output of academic science, and the other relating to the exploitation of ideas and concepts rather than necessarily being specifically scientific."[30] The Royal Society report goes on to argue the need "to explore ways of better measuring the inputs, outputs and impacts of the global scientific landscape."[31]

The authors of the 2010 QDR recognized that: "[t]he global economy has changed, with many countries now possessing advanced research, development, and manufacturing capabilities. Moreover, many advanced technologies are no longer predominantly developed for military applications with eventual transition to commercial uses, but follow the exact opposite course."[32] In defining a risk management framework for defense, the report elaborated on the future challenges risk stemming from globalization of S&T (emphasis added):

Future Challenges Risk[33]

> *A number of factors related to research and development will, over time, generate increased risk to America's technological edge. As global research and development (R&D) investment increases, it is proving increasingly difficult for the United States to maintain a competitive advantage across the entire spectrum of defense technologies. Even at current, relatively robust levels of investment, the DoD S&T program is struggling to keep pace with the expanding challenges of the evolving security environment and* ***the increasing speed and cost of global technology development****. The Department's options for managing risk with respect to S&T must be synchronized with efforts by other agencies as well as the private sector. The health of the U.S. R&D base is well beyond the mission of an individual department; it is also driven by commercial and academic interests beyond the direct influence of DoD spending. To assure future technology competence, the Department will continue to be a leading proponent of education standards and opportunities relevant to the technology requirements to enhance national security. The Department will consider the scope and potential benefits of an R&D strategy that prioritizes those areas where it is vital to maintain a technological advantage. This effort will be coupled with further work to assess how best to work with the academy and industry, as well as key international allies to leverage breakthroughs and avoid duplication.*

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[30] Knowledge, Networks and Nations: Global scientific collaboration in the 21st century. ISBN 978-0-85403-890-9. Copyright The Royal Society, 2011, p. 13.

[31] Ibid.

[32] Quadrennial Defense Review Report 2010. U.S. Department of Defense. February 2010, p. 84.

[33] Ibid. pp. 94-95.

This description of future challenges risk describes the need for a holistic approach that engages other government agencies, academia, the private sector and key allies in its efforts to cope with the "increasing speed and cost of global technology development." The study committee concurs with this assessment but observes that four years after publication, efforts to develop such an approach are not evident.

More recently, a Defense Science Board (DSB) Task Force on Basic Research, assessed DoD's posture in light of the ongoing globalization of basic research and offered a number of recommendations aimed at "coordinating with, reaching out to, and harvesting the results of basic research around the world."[34] A separate, but related issue identified by the DSB task force is the absence of a DoD technology strategic plan, without which "lists of priority science or technology areas cannot be specified with sufficient clarity relative to quantitative performance, to timing, or to feasibility and desirability."[35] The recently released "Reliance 21" document identifies 17 technical areas of cross-cutting importance to the DoD and charges a Community of Interest (COI) associated with each technical area with the responsibility to "coordinate international S&T engagement for their technical area."[36] While Reliance 21 provides a useful foundation from which to build, it falls well short of the holistic approach called for in the 2010 QDR.

Finding I

Sustained mission success will require the DoD to selectively maintain technological superiority while effectively leveraging advances occurring throughout the global S&T landscape.

There is ample evidence that the DoD cannot maintain technological superiority across the full spectrum of technologies that underpin military capabilities, but it will remain important to sustain an edge in strategically critical areas. To do so, however, requires global awareness of related research and ongoing evaluation of the best engagement mechanism(s) for building and sustaining a leadership position.

There is a much broader array of technologies with military utility that will be driven by market forces and non-DoD investments. In such cases, DoD should be a "fast follower"—that is, positioned to build rapidly on the advances spawned by others whether in the US or abroad. Science and technology monitoring remains important, but should be aided by a variety of information technologies and tools to maintain pace with the geographically distributed and

[34]Task Force on Basic Research. Defense Science Board. Department of Defense. January 2012, p. 94.

[35]Ibid, p. 75.

[36]Reliance 21. Operating Principles: Bringing Together the DoD Science and Technology Enterprise. January 2014, p. 5-6.

steadily expanding global S&T enterprise. Science and technology collaboration can pay off not only in developing new military-related technologies, but also in establishing and nurturing positive relationships around the world.

As evidenced by numerous citations from DoD-generated documents, the DoD clearly recognizes the importance of both maintaining awareness of global S&T advances and increasing engagement with other parts of the U.S. government, industry, academia, and international allies to leverage its own investment resources. There are many programs underway across the department targeting these objectives, some of which will be described in the following chapter. But what remains lacking is a department-wide strategy to mitigate the future challenges risk defined in the 2010 QDR.

1.4 Summary

The global S&T landscape is both complex and dynamic. Global situational awareness provides researchers with the knowledge necessary to work at the leading edge of their fields (and to collaborate accordingly) and serves as invaluable input at an institutional level to inform S&T budgets, international collaboration policies, and strategies for technological and economic competitiveness and national security.

Many mechanisms for international S&T engagement exist, such as publication scans and bibliometric analyses, researcher exchanges and visits, scientific conferences and meetings, international research funding, and collaborative research activities. Each mechanism ranges on the spectrum from passive and requiring little in-person engagement to ones that involve sustained researcher-to-researcher interaction and knowledge exchange. While missions and objectives vary across S&T organizations, universities, industries, and governments employ many similar approaches for international S&T engagement.

The need for DoD to maintain global awareness of S&T and to engage and/or collaborate in appropriate areas of S&T is critical if the United States is to remain economically and militarily competitive. As science and technology continues to globalize, the DoD research enterprise must find ways to leverage advances being made outside of the United States. In fact, an important motivator for international engagement is the recognition that there are many areas of S&T for which the cutting edge will not be driven by the defense research enterprise, and significant investments are being made in each of these areas by the international public and private sectors.

While defense research collaboration plays an important role, the DoD needs to identify opportunities for substantive engagement with researchers and institutions outside of its historical allied relationships. Strategies for identifying such opportunities should clearly define objectives for engagement; articulate implementation action plans that consider a foreign collaborator's unique technological, cultural, and geopolitical circumstances; establish mechanisms to ensure that the knowledge gained from engagement is accessible throughout the enterprise; utilize metrics that assess the effectiveness and success of outcomes.

Subsequent chapters will assess DoD's current international S&T activities and its approaches for global S&T engagement and awareness, as well as examine opportunities for the DoD to adapt, adopt and leverage engagement approaches used by the public and private sectors in the United States and abroad. Through these examinations, the committee will identify opportunities to improve DoD's approach for maintaining global S&T situational awareness and for leveraging global S&T developments through appropriate engagement and collaboration efforts.

2

Global S&T Engagement by the DOD

"The U.S. S&T workforce must be able to quickly recognize movements in the frontiers of knowledge and the potential for new military applications stemming from new knowledge or a combination of existing knowledge and new technology. The required awareness can be maintained only if the U.S. S&T workforce is a participant in the global S&T community. This is true for the DOD S&T workforce as well."[1]

The United States has a long history of defense science cooperation and collaboration with its allies. For example, since World War II, the United States has worked with researchers from its "five eyes" partners (United Kingdom, Canada, Australia, and New Zealand) under The Technical Cooperation Program (TTCP). The Department of Defense (DoD) is also an active participant in science and technology (S&T) fora such as the North Atlantic Treaty Organization's Science and Technology Organization (NATO STO) and regularly engages, coordinates, and collaborates with its allied defense counterparts through ongoing dialogues and scientist and engineer (S&E) exchanges at DoD's laboratories and research centers. In addition, each of the Services maintain an overseas presence to monitor technological developments (and to collaborate as necessary) in order to prevent "technological surprise."[2]

DoD's international S&T engagement and collaboration efforts serve two purposes: to maintain awareness of, and to ultimately leverage, militarily relevant S&T capabilities developed outside the United States, and to develop and nurture

[1]Globalization of S&T: Key Challenges Facing DOD. Timothy Coffey and Steve Ramberg. National Defense University: Center for Technology and National Security Policy. February 2012. p. 1.

[2]Four definitions of Technology Surprise include the following: (1) a major technological breakthrough in science or engineering (generally rare events, enabled by experts within a field); (2) a revelation of secret progress (by a second party which may have an unanticipated impact); (3) temporal surprise (when a party makes more rapid development or advancement in a particular technology than anticipated); and (4) innovative technology applications (such innovations often do not necessarily require technical expertise, but rather the creativity to use available resources in a new way). Avoiding Technology Surprise for Tomorrow's Warfighter: A Symposium Report. National Research Council. Washington, DC: The National Academies Press. 2009.

strategic defense relationships with other countries. The ongoing globalization of research and development, as well as the interconnectedness of international research communities, has important implications for both of these defense objectives. In fact, the 2014 Quadrennial Defense Review (QDR) acknowledged that: "[u]nprecedented levels of global interconnectedness through technology, travel, trade, and social media provide common incentives for, and more effective means of, fostering international cooperation and shared norms of behavior."[3] Security under globalization needs to depend less on technological dominance and more on cooperative relationships. This is particularly important, as there are areas of science and technology where the leading edge is not driven by the military research establishment, thus necessitating collaboration to simply maintain technological competency.

Chapter 2 examines current approaches used by the DoD for engaging the global research landscape and for maintaining global S&T awareness. Section 2.1 begins with a brief overview of the components of the DoD research enterprise, then provides a more detailed description of the Army, Air Force, and Navy S&T enterprises. Section 2.2 describes DoD's most recent International Science and Technology Strategy, and Section 2.3 examines mechanisms for global S&T awareness and engagement currently employed by the DoD, specifically the Services' international field offices and corporate laboratories. Section 2.4 looks at the current DoD S&T workforce, and Section 2.5 concludes by examining current efforts throughout various components of the DoD to coordinate and leverage others' global S&T engagement and awareness practices, as well as to build an integrated picture of the global S&T landscape across the entire Defense Research Enterprise (DRE).

2.1 The U.S. Defense and Service (Navy, Air Force, Army) Research Enterprise

The defense research enterprise (DRE) is comprised of researchers at each of the Services' (Navy, Air Force, and Army) laboratories and warfare centers, University-Affiliated Research Centers (UARCs), and Federally Funded Research and Development Centers (FFRDCs)[4]. DoD also funds a large community of extramural researchers in academia and industry. The objective of the internal and extramural research portfolios is to fund the most promising, relevant technologies and, therefore, includes international researchers as appropriate.

[3]Quadrennial Defense Review 2014. U.S. Department of Defense. p. 6.

[4]UARCs and FFRDCs are non-profit research centers sponsored and primarily funded by the U.S. government. There are 13 DoD-sponsored UARCs, 5 of which are sponsored by the Army and 5 by the Navy. There are 10 DoD-sponsored FFRDCs, 3 of which are sponsored by OSD, 3 by the Air Force, 2 by the Army, and 1 by the Navy. http://www.defenseinnovationmarketplace.mil/UARC_FFRDC.html. Last accessed on January 28, 2014.

Within the three Services, S&T is sponsored by the Service offices of research: Office of Naval Research (ONR), Air Force Research Laboratory (AFRL), and the Army Research Laboratory (ARL). Each of these offices is provided a budget from its corresponding acquisition executive[5] (see Figures 2-1 through 2-3 for organizational structure) and is tasked with managing and executing its organization's S&T portfolio.

Numerous components of the DRE have international activities and responsibilities for international engagement and collaboration. Within the Office of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)), this includes the ASD(R&E), the Office of Technical Intelligence, the Office of Basic Research, the Office of International Cooperation, and liaisons to the NATO STO, TTCP, and other bi- and multi-lateral S&T dialogues. In addition to maintaining international S&T offices (discussed in greater detail in subsequent sections) and international program offices,[6] the Service laboratories (including those on university campuses and DoD-funded university researchers) engage and collaborate with international contacts. Sections 2.1.1 through 2.1.3 provide a more detailed description of each of the Services' S&T enterprises. Section 2.1.4 describes Amy and Navy medical research units overseas which also provide useful platforms for international collaboration but were not studied in depth by the committee.

2.1.1 Army S&T Enterprise

The Army's S&T enterprise is composed of five major units, [7] the largest of which is the Army Materiel Command (AMC) holding approximately 72 percent of the Army's S&T budget.[8,9] The AMC's S&T budget is managed by the Research, Development and Engineering Command (RDECOM) and executed by ARL, the Research, Development and Engineering Centers (RDECs), and RDECOM Forward Element Commands (RFECs).

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[5]The Service acquisition executives are the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN(RD&A)); the Assistant Secretary of the Air Force for Acquisition (ASAF(AQ)); and the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(AL&T)).

[6]The Services international program offices include the Office of the Deputy Assistant Secretary of the Army for Defense Exports and Cooperation (DASA(DE&C)), the Office of the Secretary of the Air Force for International Affairs (SAF(IA)), and the Navy International Programs Office (NIPO).

[7]Army Materiel Command (AMC), U.S. Army Medical Research and Materiel Command (USAMRMC), Army Corps of Engineers (USACE), Army Space and Missile Defense Command (USASMDC) and HQDA, G1, Personnel.

[8]http://defenseinnovationmarketplace.mil/resources/042513_Miller_NDIA%20SET_Army%20ST%20Overview_Public_Release.pdf. Last accessed on January 28, 2014.

[9]Army 6.1 and 6.2 funding accounts for approximately 56% of the Army's total S&T budget. For FY 2014, total S&T funding (6.1, 6.2, and 6.3) for the Army was $2,406.3 million (6.1 alone was $436.7 million). http://docs.house.gov/billsthisweek/20140113/113-HR3547-JSOM-C.pdf?dm_i=1ZJN,248QJ,E29EFK,7N6HU,1. Last accessed on February 1, 2014.

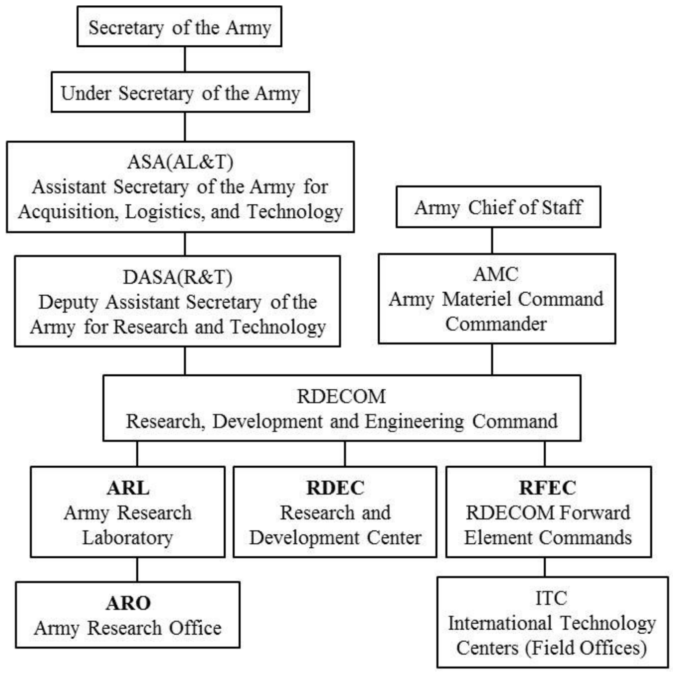

FIGURE 2-1 Army S&T Enterprise. SOURCE: Committee generated.

ARL is responsible for the majority of the Army's basic (~20 percent of funding is 6.1) and applied (~ 40 percent of funding is for 6.2) research, which is conducted either in-house or through research grants, contracts, or cooperative agreements with researchers from academia and industry. ARL is composed of six technical directorates[10] and the Army Research Office (ARO), which funds extramural research conducted by, primarily, single-investigator academic research efforts, as well as UARC and specially tailored outreach programs. ARL researchers also leverage research and development (R&D) from other U.S. government agencies, including the Defense Advanced Research Projects Agency (DARPA), Defense Threat Reduction Agency (DTRA), Department of Energy (DOE) labs, Department of Homeland Security (DHS), National Institutes of Health (NIH), and National Aeronautics and Space Administration (NASA).

The RDECs[11] are closely associated with the Army's commodity commands, providing technology solutions to meet current operational needs, as well as organic Army R&D capability.

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[10]Weapons and Materials, Sensors and Electronic Devices, Information Technology, Vehicle Technology, Human Research and Engineering, and Survivability and Lethality.

[11]Aviation & Missile Research, Development & Engineering Center (AMRDEC); Armaments Research, Development & Engineering Center (ARDEC); Communications-

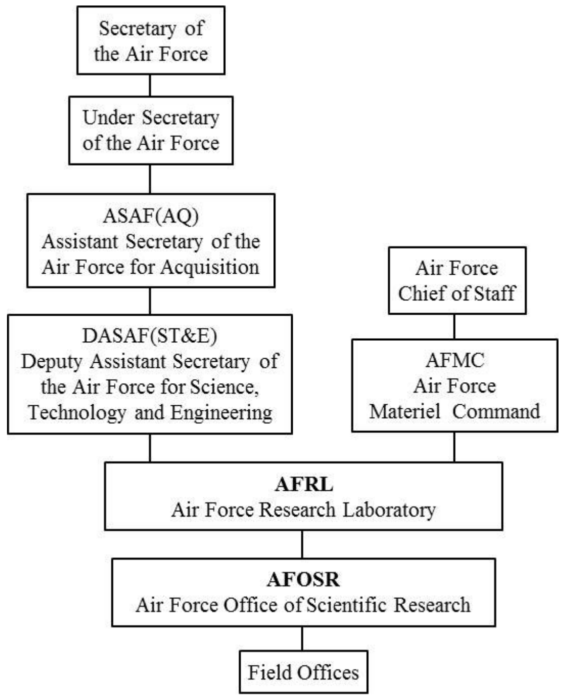

FIGURE 2-2 Air Force S&T Enterprise. SOURCE: Committee generated.

The RFECs are responsible for managing and coordinating the Army's international S&T activities[12] through its International Technology Centers (ITCs)[13] and Field Assistance in Science and Technology (FAST) teams. The three regional ITCs are located in Tokyo, Japan (ITC–Pacific); Santiago, Chile (ITC–Americas); and London, United Kingdom (ITC–Atlantic). The goal of the ITCs is to foster

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Electronics Research, Development & Engineering Center (CERDEC); Edgewood Chemical Biological Center (ECBC); Natick Soldier Research, Development & Engineering Center (NSRDEC); Tank Automotive Research, Development & Engineering Center (TARDEC).

[12]Other Army S&T organizations, such as the Medical Research and Materiel Command (MRMC), also have overseas offices to maintain cognizance of foreign S&T developments or to conduct research. MRMC has established several medical-related collaboration centers that include CPHRL, AFRIMS and USAMRU-E, USAMRU-K Army International Medical Laboratories on Infectious Disease. As this study is focused on DOD international science and technology challenges and opportunity at the 6.1 and 6.2 research levels, only activities associated with the RDECOM/RFEC/ITC are addressed.

[13]The operating budgets for the field offices are approximately: $3.96 million (ITC-Atlantic), $1.87million (ITC-Americas), and $2.33 million (ITC-Pacific). Documents provided by AFOSR.

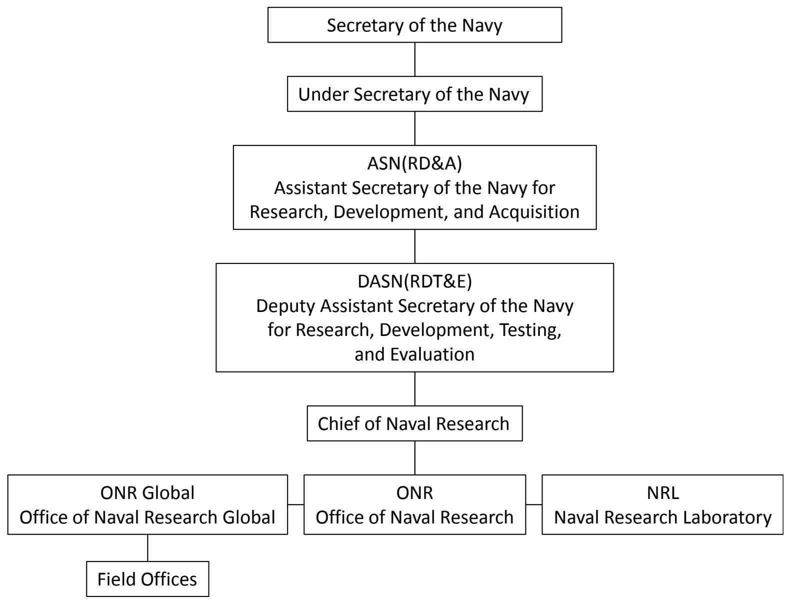

FIGURE 2-3 Navy S&T Enterprise. SOURCE: Committee generated.

international relationships and to identify, assess, and facilitate cooperative science and technology fundamental research opportunities.[14] Historically, all of the Army international offices were organized under and wholly supported by ARO; following the establishment of RDECOM in 2004, the international field offices were transferred into the RFECs.

2.1.2 Air Force S&T Enterprise

The Air Force's S&T budget[15] is managed by the Air Force Materiel Command (AFMC) and executed by the Air Force Research Laboratory. AFRL is composed of eight technical directorates and the Air Force Office of Scientific Research (AFOSR). The eight directorates[16] conduct in-house research or are

[14]http://74.52.18.198/~iassaor/files/Cynthia%20Bedell%20-%20US%20Army%20RDECOM.pdf Retrieved online March 31, 2014.

[15]Air Force 6.1 and 6.2 funding accounts for approximately 71 percent of the Air Force S&T budget. For FY 2014, total S&T funding (6.1, 6.2, and 6.3) for the Air Force was $2,392.0 million (6.1 alone was $524.7 million). http://docs.house.gov/billsthisweek/20140113/113-HR3547-JSOM-C.pdf?dm_i=1ZJN,248QJ,E29EFK,7N6HU,1. Last accessed on February 1, 2014.

[16]Space Vehicles, Information, Aerospace Systems, Directed Energy, Materials & Manufacturing, Sensors, Munitions, Human Performance.

under contract to external entities. AFOSR manages the Air Force's entire basic research program, which is carried out extramurally in academia, industry, and other government laboratories (approximately 70 percent), as well as intramurally with AFRL (approximately 30 percent).

The AFOSR International Office (AFOSR/IO), located in Arlington, Virginia, serves three main functions: (1) it is the international point of contact for AFOSR (establishing international research initiatives with world-class researchers and institutions to support AFOSR programs, identifying and advocating international opportunities to work with AFOSR, providing technology security screening and training for international efforts to include AFOSR and AFRL, and administering the Engineer and Scientist Exchange Program (ESEP) and Window-on-Europe, -Asia, and -Americas Program); (2) it oversees the liaison for basic research activities with all of the Americas, and (3) it supports the overall AFRL International Enterprise in developing strategies, representing AFRL at international forums, maintaining a database of international AFRL activity, performing data-mining and related training, publishing the tri weekly AFRL International Notes, hosting the annual AFRL-wide IPOC (international point of contact) Workshop, and representing AFRL as the international liaison in the National Capitol Area.[17]

AFOSR also has three forward-deployed detachments that "provide direct interchange with members of the scientific and engineering community and encourage the establishment of beneficial relationships between Air Force scientists and engineers and their foreign counterparts within their respective geographical and technical areas of responsibility."[18] The three detachments are located in Tokyo, Japan (Asian Office of Aerospace Research and Development, or AOARD); Santiago, Chile (Southern Office of Aerospace Research and Development, or SOARD); and London, United Kingdom (European Office of Aerospace Research and Development, or EOARD), and their mission is to integrate and support AFRL fundamental research with discoveries of emerging foreign science.

2.1.3 Navy S&T Enterprise

The S&T budget[19] for the U.S. Navy and U.S. Marine Corps (USMC) is managed and executed by the Office of Naval Research, located in Arlington, Virginia. ONR has six S&T departments that fund basic research programs at U.S. universities, government and non-government research laboratories, and private industry.

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[17]http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=8971. Retrieved March 31, 2014.

[18]Ibid.

[19]Navy 6.1 and 6.2 funding accounts for approximately 70% of the Navy's S&T budget. For FY 2014, total S&T funding (6.1, 6.2, and 6.3) for the Navy was $2,077.3 million (6.1 alone was $619.3 million). http://docs.house.gov/billsthisweek/20140113/113-HR3547-JSOM-C.pdf?dm_i=1ZJN,248QJ,E29EFK,7N6HU,1. Last accessed on February 1, 2014.

The Naval Research Laboratory (NRL) is the Navy's corporate research laboratory and conducts a broad-based multidisciplinary program of scientific research and advanced technological development. It is composed of four directorates[20] that conduct scientific research and the Naval Center for Space Technology. In 2012, NRL received by direct appropriation only a small portion of its overall budget as core funding from ONR.

The Office of Naval Research Global (ONR-G) provides worldwide S&T solutions for current and future naval challenges and had a budget of $29.9 million in 2013[21]. ONR-G engages the broad global research community to build and foster international collaboration, and it maintains an overseas presence with international field offices in London, Tokyo, Singapore, Santiago, and Prague. ONR-G staff include associate directors who "serve as the international arm of ONR, help to shape the Navy's international engagement strategy, and establish insight into research agendas of ONR, NRL, and the NRE [Naval Research Enterprise] organizations,"[22] as well as science advisors who serve around the world as a command's senior liaison with S&T organizations in government, academia, and industry. ONR-G also sponsors programs that foster collaboration between Navy personnel, scientists, and technologists around the world, including the Visiting Scientists Program, Collaborative Science Program, and Naval International Cooperation Opportunities in S&T Program (NICOP).

2.1.4 Army and Navy Medical Research Units Overseas

The U.S. Navy Bureau of Medicine and Surgery and the U.S. Army Medical Research and Materiel Command have medical research units, sometimes referred to as labs, overseas. The primary focus of these units is infectious disease research, epidemiology and biosurveillance. The overseas Navy Medical Research Units (NMRU) are located in Cairo, Egypt (with a field site in Accra, Ghana); Lima, Peru (with a field site in Iquitos, Peru); and Singapore (with a field site in Phnom Penh, Cambodia). [23] The Army's overseas medical labs, with a primary focus on endemic diseases and biosurveillance, are located in Nairobi, Kenya; Bangkok, Thailand; and Tiblisi, Georgia. The Army also has a lab in Germany whose main focus is psychological health of U.S. troops.[24] Since the Army and Navy medical research labs overseas have a main focus on medical surveillance and epidemiology and do not have fundamental research (the main

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[20]Systems, Materials Science & Component Technology, Ocean & Atmospheric Science & Technology, and Naval Center for Space Technology.

[21]Briefing received from ONR-Global on March 26, 2013.

[22]http://www.onr.navy.mil/Science-Technology/ONR-Global/associate-directors.aspx.

[23]Available at http://navymedicine.navylive.dodlive.mil/archives/5906 (last accessed on May 19, 2014).

[24]Personal communication with Drs. John Frazer Glenn and George V. Ludwig, Principal Assistant and Deputy PA, respectively, for Research and Technology, U.S. Army Medical Research and Materiel Command, Fort Detrick, MD on April 22, 2013.

focus of this study) as a primary focus, their operations were not explored in depth by the study committee. A small group from the study committee did visit the Army's overseas lab in Bangkok in August 2013 to learn about their operations.

2.2 Office of the Secretary of Defense International Strategy

In 2005, DDR&E[25] (Director of Defense Research for Research and Engineering) issued guidance to the DRE through the International Science and Technology Strategy[26] for the U.S. Department of Defense with the goal of facilitating international cooperation through S&T collaboration. The strategy presented the rationale for international S&T cooperation and proposed the following six broad areas of interest: basic research, information assurance, battle space awareness, force protection, reduced cost of ownership, and transformation initiatives. The strategy also described a tiered approach to international cooperation that begins with Services' and Agency's program officers who have global awareness of their technical discipline. The guidance states that each Service should maintain international technical representatives to "serve as liaison with the international S&T community; not only government to government, but with academic and industrial entities as well." The next tier consists of international agreements—for the exchange of people, information and material—that are typically government to government and executed through NATO STO, TTCP, and bi- and multi-lateral agreements. While the strategy states the expectation that DoD will maintain an international S&T program and that "reasonable investments" will be made, it neither provides specifics on implementation, nor does it provide measures of effectiveness beyond "increases in defense technological capability" for the United States and our allies.

Reliance 21,[27] the overarching framework of the DoD's S&T joint planning and coordination process, assigns responsibility for coordination of international S&T engagement to a Community of Interest (COI) for each of 17 crosscutting technical areas, but defines no specific outcomes or strategies for doing so. The technical areas of interest are shown in Figure 2-4. The committee observes that virtually all of these areas are of keen interest both to other nations' defense establishments and to researchers in public and private sectors alike.

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[25]The 2011 signing of the National Defense Authorization Act resulted in the renaming of DDR&E to ASDR&E (Office of the Assistant Secretary of Defense for Research and Engineering).

[26]International Science and Technology Strategy for the United States Department of Defense. Department of Defense Research & Engineering. Approved for public release; distribution unlimited. April 2005.

[27]Reliance 21. Operating Principles: Bringing Together the DoD Science and Technology Enterprise. January 2014,p. 6.

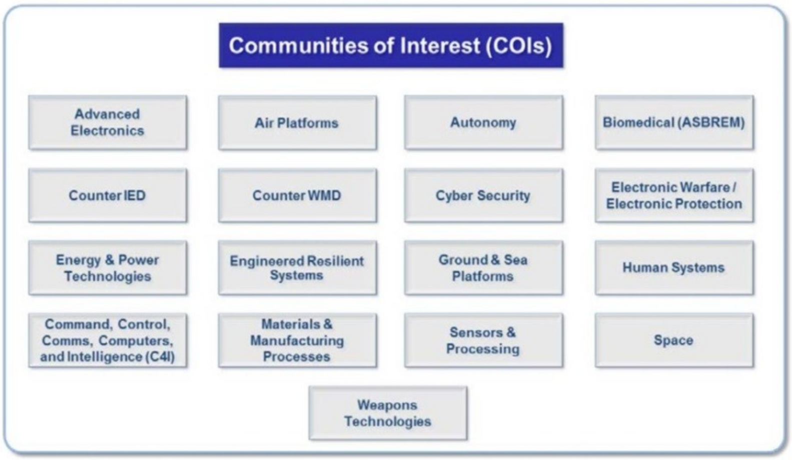

FIGURE 2-4 Technical areas of interest identified in Reliance 21. SOURCE: DoD S&T International Strategy and Priorities. Mr. Alan Shaffer. Acting Assistant Secretary of Defense Research & Engineering. Briefing on April 3, 2013.

The committee was informed in April 2013 that an updated international strategy for R&D is under development, but did not have access to such a strategy prior to report publication.

2.3 Mechanisms for Global S&T Engagement by the DoD

Based on discussions with researchers and leaders across the DRE, the study committee believes DoD is heavily reliant on extramural researchers to maintain comprehensive global awareness of what is happening in their respective fields. However, such a strategy is inadequate as DoD awareness of international S&T cannot be maintained through its extramural research communities alone. In addition, intra-DRE knowledge exchange is not sufficient for fulfilling the technology-prospecting and partnership-building missions of the international arms of the DRE (e.g., the Services' international offices in the United States and overseas).

This section describes global S&T engagement mechanisms that are currently in place by various components of the DRE, including: conference support and attendance; overseas meetings with non-U.S. researchers at universities, industry, and foreign government S&T offices; scientist exchanges; overseas research funding (small seed grants); data analytics and horizon scanning; TTCP; NATO STO; and U.S. government bi- and multilateral S&T cooperation agreements. All of these mechanisms, excluding data analytics and horizon scanning, involve direct contact with international technologists, that is, one has to be part of and directly engage with the community to leverage it.

The following descriptions and observations of engagement mechanisms currently in place by the DRE are based on briefings and discussions with the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) and the Service S&T organizations (AFOSR, ONR, and Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology [ASA(AL&T)]) on their international programs, as well as observations from committee subgroup visits to the Services' corporate research laboratories in Adelphi, Maryland; Washington, D.C.; and Dayton, Ohio, and to the Services' international field offices in Tokyo, Japan, and London, England.

2.3.1 Global Engagement by the Services' International Field Offices

In April and October of 2013, two committee subgroups met with staff from each of the Services' international field offices. The purpose of these meetings was to provide the study committee insight into how each office operates and what each of the offices sees as the greatest opportunities and challenges for global S&T engagement. During these meetings, staff from each office shared their perspectives on the following themes: mission, mechanisms for technology awareness, relationship building, enterprise coordination and connectivity, and metrics. Appendix D has a list of some, but not all, of the questions posed by the committee members during their visits. Following are observations based on these discussions.

Each of the field offices emphasized with the committee the importance of having a consistent overseas presence for each of their research enterprises. Without having an on-the-ground presence, the field offices indicated that their ability to build and maintain trusted relationships with the international research community would be significantly more difficult, and in some cases likely impossible. In addition to providing opportunities for in-person interactions, which is a critical cultural component for relationship building (particularly in Asia), an overseas presence helps to establish for the Service research offices a reputation as an active contributor to and sponsor of collaborative, basic research.

While the Services' field offices are colocated (in London, England; Santiago, Chile; and Tokyo, Japan), each has unique S&T engagement objectives. For example, while ONR-G program managers spend a significant amount of time attending conferences and visiting international researchers (with university and industry engagement targeted to provide connections for specific U.S. counterparts), the Air Force field offices engage almost exclusively with universities due to their basic research mission. In contrast, the Army RFECs/ITCs, while also providing conference support and seed grants, spend their time predominantly on government-to-government activities such as bilateral and multilateral agreements and operational exercises due to their focus on R&D and operational support and cooperation. In addition to unique missions, the field offices have varied organizational structures and available resources.

The field offices have a range of mechanisms for global S&T awareness and engagement, such as organizing international conferences and workshops

and hosting S&E visits from the United States. Such in-person engagement allows field office staff to not only remain knowledgeable of the state-of-the-art in their respective technological fields, but also improves their ability to maintain in-country and regional awareness of emerging S&T developments. Field office staff also facilitate research collaborations between U.S. and foreign researchers and build relationships with relevant foreign S&T enterprises primarily at universities. To develop collaborative research programs that are attractive to foreign collaborators, as well as mutually beneficial, field office staff noted the importance of understanding a host country's unique culture, as well as science and technology gaps and strengths. One such example is the joint U.S.-Thailand Armed Forces Research Institute of Medical Sciences (AFRIMS), in which the U.S. and Thai components have worked collaboratively for the past 50 years on tropical infectious disease research and development of diagnostics and treatments.[28]

Field office staff also discussed mechanisms for providing seed funding for in-country non-U.S. researchers. While seed funding represents an overall small investment, field office staff emphasized its importance for establishing new relationships, for accessing foreign research capabilities, and for leveraging research investments within their home offices and across each of the colocated field offices.

When asked about mechanisms for capturing and sharing relevant S&T information, some field office staff indicated that trip reports and technology papers are frequently prepared and deposited in various online knowledge management systems (that are accessible within, but not across, each of the Services). As an alternative to more formal mechanisms, some field office staff indicated that they stay abreast of, as well as share, relevant S&T information with the appropriate individuals by leveraging their own professional scientific networks.

Based on discussions with the field offices, the committee identified several challenges, as well as opportunities, to improve S&T engagement and awareness approaches, in areas such as staffing, conference travel and attendance, enterprise-wide coordination and reachback, success metrics, and coordination across DoD and other U.S. government offices with international S&T activities and responsibilities.

Given the small number of field office personnel tasked to maintain awareness of in-country and regional S&T development, the committee asked the field offices to discuss their staffing strategies. While the absence of a con-

[28]The Armed Forces Research Institute of Medical Sciences (AFRIMS) originates from a 1958 joint U.S.-Thailand study on cholera. This collaboration led to the establishment of the Southeast Asia Treaty Organization (SEATO) Cholera Research Laboratory following an exchange of letters of agreement between the Thai Foreign Ministry and the U.S. Department of State in 1960. Since 1977, the laboratory has been a binational institute jointly operated by the Royal Thai Army and the United States as a special foreign activity of the Walter Reed Army Institute of Research under the U.S. Army Medical Research and Materiel Command.

sistent staffing strategy across the Services might be expected due to the varied international field office missions, the committee did not observe consistent best practices for staffing. This is problematic, as the committee believes effective staffing criteria—which includes both broad and narrow technical competency, as well as in-country experience and language fluency—are critical to ensure field office success. While some field offices highlighted specific technical expertise or established in-country professional networks as staffing criteria, others did not appear to have any criteria. The latter highlights another committee observation, that field office staff positions are not seen as career-enhancing opportunities, thus making it difficult to attract and retain the best possible field office program managers.

In agreement with testimony from the field offices, the committee believes that conference attendance provides a cost-effective way for field office staff to meet emerging and eminent researchers in targeted fields and provides an opportunity to meet researchers from countries in which relationships do not exist. Not engaging with other S&Es may result in DoD in-house research becoming insular and noncompetitive. Government-wide and DoD S&T restrictions (and delays) on travel and conference attendance limit the ability of program managers to meet new researchers, deteriorate existing relationships, and hinder the ability of the field offices to fulfill their missions in a cost-effective way.[29]

The committee believes that effective reachback mechanisms are important for enabling enterprise-wide S&T awareness within and across each of the Services. By creating dynamic bidirectional information-sharing feedback loops between the field offices and other components of the DRE (e.g., DoD program managers, in-house S&Es at Service laboratories and research centers, and DoD-funded university researchers), the field offices can remain knowledgeable of the S&T strengths and needs of their respective research enterprises. This, in turn, can help to improve field office S&T scouting efforts and to better leverage research investments made by the field offices and by DoD program managers in the United States. Effective reachback and feedback mechanisms can enable program managers (both in the United States and overseas) to more effectively provide real-time insertion of foreign research and researchers into the home organization's research activities and programs.

However, based on its visits to the Tri-Service field offices in London and Tokyo, the committee did not observe effective, consistent, or systematic reachback mechanisms for capturing and sharing S&T information and knowledge. Discussions with field office staff, as well as with other components of the DRE, suggest that DoD researchers are unable to fully take advantage of trip reports and technology papers filed in online knowledge management systems due to inaccessibility issues, poor system searching capabilities, and insufficient or

[29]Following past year travel cuts and restrictions (similar to those described by the Services S&T field offices), Australia's Defense Science and Technology Organisation (DSTO) reexamined its strategy and loosened its travel restrictions to better support international engagement.

irrelevant information. While the committee acknowledges the importance of informal, ad hoc, and personality-driven reachback mechanisms (e.g., program managers that rely on their professional networks to connect their home offices and U.S.-based researchers with foreign S&T capabilities), such mechanisms provide only a limited perspective. Further, overreliance on these informal networks can lead to developing technology scouting blinders that inadvertently ignore key technology areas and important communities of interest. Given these observations, there may be opportunities for the Services to reexamine current mechanisms for capturing, managing, and sharing information and to consider knowledge management systems that provide "push" and "pull" search-and-share functionality.

Some of the field offices cited matching funds (from their home offices or elsewhere) and transition of research to U.S. program offices as a primary success metric.[30] While these metrics are useful for demonstrating cost sharing, they do not effectively assess how well the field offices are engaging with current international collaborators, identifying emerging, futures-oriented S&T for which existing research programs do not exist stateside, or establishing strategic, long-term relationships with S&Es and institutions that may become important future collaborators. For these reasons, the committee believes there are opportunities for the Service offices of research to establish clear objectives and measurable performance metrics for the field offices (as well as other components of the DRE with international S&T responsibilities). Ideally, metrics would provide insight into how successfully knowledge is captured, shared, and used so that the best global S&T benefits the DRE and that the global S&T landscape accurately informs defense science policies and decision making.

In an environment of constrained or even shrinking budgets, collaboration and coordination between the field offices should be a force multiplier for DoD to enhance its international S&T engagement efforts. As such, the committee believes there are opportunities for each of the field offices to better leverage tri-Service knowledge and investments. While coordinating personnel exchanges between field offices,[31] hosting workshops and S&E visits, and occasionally co-funding seed grants for overseas research are useful, they are insufficient for fully leveraging tri-service investments.[32] It appears to the committee that while each of the Service field offices has significant knowledge about the internation-

[30]Examples of success include Magnetic Energy Recovery Switch transition to ONR-Global's Joint Capability Technology Demonstration (JCTD), Nippon paint that turns opaque when correct thickness (ONR-G), and Nano-bio-info partnership with Korea (AOARD).

[31]For example, "Ceramics for High Energy Lasers" was identified and initiated by a join AOARD/ONRG project in Tokyo and later transferred to the Army because of the same program manager's movement from one service to another. It is now used by all three Service laboratories.

[32]Programs such as the AOARD-Taiwan Collaborations in Nanotechnology and with Korea in Nano-Bio-Info, which have been in place for more than 10 years, are good examples of international S&T engagement and may offer lessons for developing new models for tri-Service collaboration.

al technology landscape, few efforts have been made to build an integrated picture of the global S&T landscape. Such a picture is important for the DoD to maintain technology awareness and to leverage DoD-wide (and potentially U.S. government-wide) S&T investments.

Based on discussions with various components of the DRE, the committee also believes that the field offices would benefit from improved feedback loops with ASD(R&E) to better position the Services' international S&T programs to more effectively inform DoD strategic decision making. In addition to participating, or remaining knowledgeable, in the Office of the Secretary of Defense (OSD) international S&T fora (e.g., TTCP and NATO STO), there are also opportunities to improve connectivity between the Services' international offices and those components within ASD(R&E) that have international S&T responsibilities (e.g., the Office of Basic Research, Office of Technical Intelligence, and Office of International Cooperation).

In addition to leveraging across DoD, the committee believes that there are opportunities for the field offices to better coordinate and leverage international S&T programs of other U.S. government offices (stateside and those forward deployed). For example, the field offices would benefit from closer coordination and collaboration with the State Department, in particular with U.S. embassies in-country and in their regions of interest. Working with U.S. embassies, which are influential and more extensively engaged with the local government and industrial sectors, may open doors for the field offices and expedite their S&T engagement and scouting efforts.[33] The field offices would also benefit from coordination with U.S. government offices that have joint international research programs and S&E exchanges, host international workshops, and maintain international offices and staff overseas, such as the Department of Energy's National Nuclear Security Administration[34] and the National Science Foundation.[35]

2.3.2 Global Engagement by the Service Laboratories

Committee subgroups visited AFRL, ARL, and NRL to learn about those laboratories' strategies and mechanisms for global S&T awareness and engagement, as well as the barriers to engagement both at the lab management level and at the individual researcher level. Appendix D has a list of some of the questions posed by the committee members during their visits.

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[33]For example, the Services' field offices in Santiago, Chile have a good relationship with the local U.S. embassy. As a result of this strong relationship, the DoD program offices have good relations with the Chilean civilian and military S&T organizations. Therefore, Chile has become a main country in South America to meet many DoD S&T needs.

[34]http://www.nnsa.energy.gov/aboutus/ourprograms/nonproliferation/programoffices/internationaloperations/overseascontactinfo. Retrieved April 7, 2014.

[35]http://www.nsf.gov/od/iia/ise/overseas-ofcs.jsp. Retrieved April 7, 2014.

Air Force Research Laboratory

At AFRL, international S&T engagement occurs primarily through a series of government-to-government agreements (there are currently active collaborations with 18 foreign governments) that are managed by the AFRL International Program Office. Using these agreements, researchers collaborate and engage with foreign partners within each of AFRL's technical directorates. AFRL researchers also engage with international researchers by attending targeted technical forums overseas to assess the potential for future collaboration. AFRL researchers can also participate in S&E exchange programs (such as the Engineer and Scientist Exchange Program, ESEP, which is primarily for civilians) or take military assignments at foreign defense laboratories.

While AFRL researchers reportedly do not derive a lot of value from trip reports produced by the international field offices (AOARD, EOARD, SOARD), they are strong advocates for the role those offices play in maintaining in-region relationships and opening doors. As an alternative to trip reports, AFRL researchers suggested that international technology trend assessments would provide more value. Such input from the field offices could serve as a very useful supplement to AFRL's annual trends and opportunities document, which is currently derived from in-house S&E inputs.

AFRL plans to increase its international engagement for several reasons, including increased advocacy by OSD, the national security rebalance to the Asia Pacific region, and the need to maximize technology investments through international collaborations. This increased focus is further supported by a key finding from the 2013 Air Force Global Horizons Study, led by the Air Force Chief Scientist, which states, "Strategic opportunity exists to leverage $1.4 trillion in global R&D investment; rapid and efficient leverage of global invention/innovation is essential to sustaining advantage." [36] An updated S&T plan is in progress and is expected to have an increased emphasis on international partnerships.

Army Research Laboratory (ARL)

At ARL, international science engagement and collaboration is managed and facilitated by the ARL International Enterprise Group, which is led by the Chief Scientist and composed of senior researchers from each of the laboratory directorates. Within each of the directorates, many ARL re-

[36] Global Horizons. United States Air Force Global Science and Technology Vision. AF/ST TR 13-01. June 21, 2013. Approved for public release; distribution is unlimited. SAF/PA Public Release Case No. 2013-0434, p. iv.

searchers have longstanding interactions and collaborative activities with international peers. ARL encourages international engagement by providing opportunities for researchers to attend conferences and to visit universities and research institutions overseas (each year, there are around 250 international S&T-related trips) and by making international collaboration a criterion for promotion of its researchers. In addition to funding international researchers, ARL has also created an international S&T website to create links between its program officers and counterparts in the United Kingdom, Israel, and Italy.

ARL researchers provided several examples of technologies for which international engagement was critical (e.g., synthesis of energetic materials and robust acoustic vector sensor and ground-penetrating radar) and emphasized that the most successful collaborations often require in-person interaction. At the same time, they also noted that security restrictions make it extremely difficult for non-U.S. research collaborators to work on site alongside ARL researchers (and to share computing facilities, patents, modeling and simulation codes, and experimental data). Given these challenges, ARL researchers noted the value of its international field offices, citing the role its ITCs play in facilitating information exchange and relationship building with international researchers. ARL management also indicated that there is some consideration of establishing an enhanced Army basic research function in their international field offices, as well as the use of analytics to future cast technology trends.

Despite having the smallest international budget of the three Services, ARL researchers noted that money is only one ingredient for successful international engagement; just as important is a culture change led by the leadership that emphasizes the importance of international engagement at the fundamental science level.

Naval Research Laboratory (NRL)

As a working capital fund activity, NRL seeks to leverage the best available S&T regardless of where that opportunity exists. Thus, despite not having a written strategy for international S&T engagement, NRL has numerous collaborative international projects (approximately 200 projects that involve 27 different countries). At NRL, S&Es work closely with ONR-G and with the Navy International Programs Office (NIPO) to develop international S&T collaborations of significant benefit to the Naval Research Enterprise. In addition, many S&Es are involved in international activities through participation in NATO STO and TTCP technical panels.

NRL researchers indicated that there are not formal requirements or policies for sharing international S&T information within the laboratory,

> across the Naval Research Enterprise, or with other components of the DRE. Instead, information sharing is ad hoc, based on S&Es personal interest, and mainly through researchers sharing of trip reports or conference proceedings with other S&Es they think might have interest in the specific topic. NRL management did not express interest in developing additional requirements for their S&Es to report or share information about international research or activities.
>
> NRL researchers noted that the long wait times for foreign visitor approvals (or denials) have resulted in missed collaboration opportunities and that severe Internet restrictions have significantly hindered key communications between NRL S&Es and their international collaborators. Some NRL researchers also indicated that insufficient public release of some research results have limited their ability to build networks, both across laboratory units and with the wider global research community.

A wide range of mechanisms are used by each of the Service laboratories to engage and collaborate with the international research community and include conference attendance, scientist exchanges, bi- and multilateral S&T cooperation agreements, and S&E participation in multilateral S&T panels and working groups of NATO STO and TTCP. Each of the laboratories acknowledged that as technology advances accelerate and defense budgets become tighter, international engagement will become increasingly important.

Each of the Service laboratories emphasized the challenges of engaging internationally due to Service- and DoD-wide restrictions on conference travel and attendance.[37] In many disciplines, conference papers are the top place for S&Es to present their work (as opposed to journal papers); if DoD researchers do not remain active participants in highly respected venues, they will not be viewed as "card carrying" members of their respective technical communities. These restrictions reduce S&Es' ability to maintain awareness of important international technological developments within their own fields, and it is particularly harmful to the careers of early-career researchers, for whom international engagement is essential for initiating and sustaining long-term relationships. All these factors combined are damaging to the reputation of the Service laboratories and of their S&Es, which, in turn, hinders the laboratories' abilities to recruit top postdocs.

Each of the laboratories also noted as barriers the lengthy process for securing project agreements and the challenges of communicating with international colleagues over secured networks. As one example, AFRL researchers indicated that for some rapidly advancing technical areas, there have been instances where the goals of the project or key personnel have shifted due to project agreement

[37]DoD makes no distinction between academic conferences and any other forms of trade shows, etc, which means that blanket denials of conferences are not subject to appeal.

delays. As another example, NRL researchers described communication barriers due to international colleagues' inability to open DoD-certified emails; AFRL researchers addressed this concern by allowing its S&Es to toggle between Non-classified Internet Protocol (NIPR) and Defense Research and Engineering Network (DREN) on their desktop computers. There are also no effective mechanisms for sustained collaboration between defense researchers and visiting foreign nationals (providing long-term escorts is not a practical solution).

While the Service laboratories are thinking about new ways to do business in a global community, the study committee did not observe specific objectives, strategies, or metrics for their international engagement efforts. Rather, international engagement is embedded in the efforts of individual laboratory S&Es. Further, without proper support and appreciation of international activities from laboratory leadership, international engagement typically becomes a lower priority as S&E workload increases.

2.4 DoD S&T Workforce

In-house DoD scientists and engineers are essential to transitioning fundamental technologies to military applications, acting as technical authorities through the life cycle of military systems and avoiding tech surprise by maintaining the technical capability to counter threats. To serve these roles, in-house researchers are expected to maintain knowledge of the state of the art, to maintain international visibility within their respective technical communities, to build productive collaborations regardless of where "the best" technical capabilities are being developed, and to ensure that insights from these global S&T engagement activities are effectively coordinated and leveraged within each of the Services' S&T enterprises and across the DRE more broadly.

To maintain global S&T awareness, DoD researchers need access to a diversity of international S&T inputs—both through scientific literature (this includes English and non-English language publications) and through international researcher-to-researcher knowledge exchange. There are a number of opportunities for in-person research engagement, such as previously discussed technical conferences and professional meetings, workshops, hosting and visiting researchers, S&E exchanges, and participating in appropriate basic international research collaborations.

Relying on one of these methods alone cannot fully paint a picture of the global S&T landscape. For example, maintaining knowledge through literature is inadequate as there can be a one to two year lag between peer-review publication and current discovery. DoD should have an in-person presence at international S&T fora to establish for itself a reputation as a leading contributor to the international research community. In fact, DoD researchers noted that missing one year of engagement is damaging and missing two years is nearly irreparable and causes DoD researchers to lose opportunities to serve as technical panel members, reviewers, and coordinators at important scientific meetings.

By not taking an outward approach for engagement, internal defense research becomes insular and non-competitive, which increases the risk of tech surprise. As discussed in earlier sections, DoD policies that deprioritize or restrict scientific engagement opportunities also make it difficult for defense laboratories to recruit and retain top postdocs and young scientists (as early career scientists and engineers recognize that their careers will be very limited if they cannot engage with their international technical communities),[38] as well as to retain leading senior researchers (who may be driven to academia or industry).

The inability of DoD's S&E workforce to sufficiently maintain global awareness of militarily relevant technical developments hurts OSD decision making not only for strategic and globally informed S&T investments, but also for technology competitiveness and national security.

While the DoD works well with its defense science counterparts around the world, it faces unique challenges establishing relationships with foreign civilian science communities. Many civilian researchers, as well as policy makers, outside of the United States are unwilling or reluctant to engage in dialogues, let alone collaborate, on open-access basic or fundamental research with the U.S. defense science community. Some of these reasons are historical and others are the result of cultural differences and economic and national security concerns. In-country international programs and outreach efforts, such as those shared by the Services' field offices in Europe and Asia, are excellent opportunities for the defense research enterprise to establish reputations in other countries and regions of the world as reliable collaborators and research colleagues in basic research.

The DoD S&T enterprise needs to be engaging and collaborating with the best researchers anywhere in the world, not only in all areas in which the DoD has basic research investments, but also those areas which the DoD has divested. It is important for leadership within and among the DoD components with international S&T responsibilities and interests to demonstrate that international S&T engagement is a priority.

Finding II

Enterprise-wide S&T situational awareness begins with ensuring its S&E workforce maintains global awareness of S&T and is appropriately engaged with the international research community.

Successful implementation of the global engagement mechanisms summarized in Table1-1 requires an S&E workforce that is motivated, equipped, and enabled to do so. First, individuals across the DRE should know that they are expected to retain global situational awareness in their respective scientific do-

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[38]Retrieved April 4, 2014 from http://www.federaltimes.com/article/20140401/MGMT03/304010005/Young-scientists-engineers-departing-DoD.

mains, and there should be clear advocacy and commitment from all levels of leadership for doing so. Second, individuals should be equipped with the necessary skills and opportunities to maintain global awareness. This includes having an appropriate understanding of a foreign collaborator's culture, languages, and unique S&T strengths and gaps; opportunities for engagement include participation in conferences, professional meetings, S&E exchanges, and collaborative research projects. Third, DoD management within each of the Service S&T enterprises should then identify barriers to effective awareness and engagement and corresponding implementable solutions to alleviate them. The study committee observed gaps in each of the above three dimensions.

2.5 Improving the Effectiveness of Current DRE Global Engagement Practices

There is ample evidence that the U.S. share of the global S&T enterprise is shrinking. The DoD's intent to maintain technological leadership in key areas is therefore dependent upon its ability to track related research worldwide. Further, in a budget-constrained environment, it is important for the DoD to be positioned to identify and leverage other relevant research advances as they emerge from the global S&T enterprise. These objectives require effective utilization of the full spectrum of engagement mechanisms summarized in Table 1-1. While the committee found evidence that every mechanism is being used somewhere in the DRE, it found no evidence that the local benefits gained are effectively leveraged across the DRE. While each Service has some unique S&T fields of interest, many fields are of cross-cutting interest to the DRE. Based on its discussions with various defense research components, the committee observed that information sharing within each Service, across the Services, and to OSD, is inadequate.

2.5.1 Coordination of International S&T Activities within the Services

Each of the Services has an expansive S&T workforce and includes S&Es at Service laboratories, warfare centers, universities (in the United States and overseas), UARCs, and FFRDCs. International engagement is critical for these researchers to build relationships with emerging, as well as eminent, researchers around the world and to maintain global awareness of emerging S&T developments within their fields. Such awareness is critical for DoD researchers to reside at the leading edge of their research fields, and increasingly, to avoid falling behind.

While bibliometric and analytic tools and researchers' expertise and assessments of their fields are important, they cannot be substitutes for in-person mechanisms for S&T engagement. As discussed previously, in-person interactions are critical for building sustained, trusted research collaborations and for better understanding each country's or region's unique S&T strengths and gaps.

Each of the Services maintains an overseas presence through its field offices, and these offices utilize a variety of mechanisms for engaging with in-country and in-region S&Es and other S&T-affiliated organizations. However, there appears to be inconsistent and weak connectivity between the field offices and their corresponding offices of research located stateside. Further, information sharing of international S&T activities is typically ad hoc and personality driven. Effective reachback from the forward-deployed S&T offices to their respective headquarter activities is key to ensuring that their international S&T activities are providing value to DoD researchers back home and supporting the broader mission of the organization.

While tasked to maintain regional S&T awareness, the Service field offices are extremely staff and resource limited, and, therefore, must prioritize which researchers and research areas to engage. This can occur in three ways. First, program managers may get requests from their laboratory or home offices to engage with specific foreign researchers or in specifically targeted research topics. Discussions with S&Es at the S&T offices and laboratories, however, suggest that this occurs infrequently. This could be the result of a disconnect between defense S&T interests and priorities or insufficient information-sharing policies and infrastructure (e.g., that is inaccessible, not useful, or lacking push-and-pull functionality). A significant challenge is determining how to provide information in a useful form; many researchers at the Service laboratories expressed frustration in their ability to derive insight and value from technology reports and trip summaries.

Second, program managers may serendipitously learn about emerging foreign technology developments (e.g., by attending a scientific conference or university visits) or entrepreneurially seek out interactions with S&Es working in fields of potential interest to their home Service's research enterprise. As discussed previously, DoD restrictions on travel and conference attendance have made the former difficult, if not impossible. The latter allows for very targeted engagement, but such a targeted approach for technology awareness can result in blinders that paint inaccurate or insufficient pictures of the research landscape. Said differently, one finds what one is looking for.

Third, program managers will award foreign researchers with small seed grants in the hopes of getting matching funds from headquarters (or the other Services' field offices) or transitioning seed grant projects to larger programs being funded by headquarters. Program managers in many of the field offices cited their ability to procure matching funds and seed grant transition as metrics used by headquarters to gauge their success. While cost sharing is a valuable metric, it does not capture how well the field offices are engaging the global S&T community, building relationships, facilitating research collaborations, identifying emerging international S&T developments, or providing inputs for building an integrated picture of the global research landscape. The study committee did not observe any metrics that clearly identified intended outcomes and measures of success for any of these objectives.

For many program officers in headquarters, international engagement is an ancillary responsibility; thus, field office reports and inputs become a low priority. This not only fuels the disconnect between the field and home offices, but also sends a message that global engagement and international S&T cooperation is not important. Leadership within each Service needs to articulate the importance of its S&T workforce being aware of global research advances within their fields (and that publications are not sufficient) and that maintaining a seat at the global research table requires engagement and collaboration with other countries—both with S&T powerhouses that already reside at the leading edge and with those developing S&T capabilities for the future.

2.5.2 Coordination Between the Services and OSD

Each of the Service S&T enterprises maintain networks of international researchers and conducts assessments of emerging S&T developments around the world in numerous research fields. Synthesizing this information across the Services could provide significant input not only to advance the state of research across the DRE but also to inform senior-level OSD decision making with respect to S&T investments and international cooperation and security policies. Based on the committee's observations, the myriad of international insights and information inputs from across the DRE do not currently appear to be collected and synthesized to provide this level of OSD insight.

The ASD(R&E) is responsible for providing S&T leadership throughout the department, including shaping strategic direction and strengthening research and engineering coordination. Successfully accomplishing this requires an integrated understanding of the global research landscape. Such an understanding cannot occur, however, if the numerous individuals and offices within each of the Services and throughout ASD(R&E) operate within their own fiefdoms with limited connectivity. One starting point for this coordination is the Research and Engineering Executive Committee (R&E EXCOM), the department's leadership forum to strengthen cross-component coordination and to enhance the effectiveness and efficiency of departmental R&E investments that cannot be sufficiently addressed by any single component. Members of the committee include the ASD(R&E), who serves as committee chair, the Army Acquisition Executive (currently the Assistant Secretary of the Army for Acquisition, Logistics, and Technology); the Assistant Secretary of the Navy for Research, Development, and Acquisition; the Assistant Secretary of the Air Force for Acquisition, and the Director of the Defense Advanced Research Projects Agency.[39] The R&E EXCOM oversight structure is shown in Figure 2-5.

[39]Available at http://www.acq.osd.mil/chieftechnologist/mission/index.html and http://www.acq.osd.mil/chieftechnologist/excom.html. Last accessed on January 27, 2014.

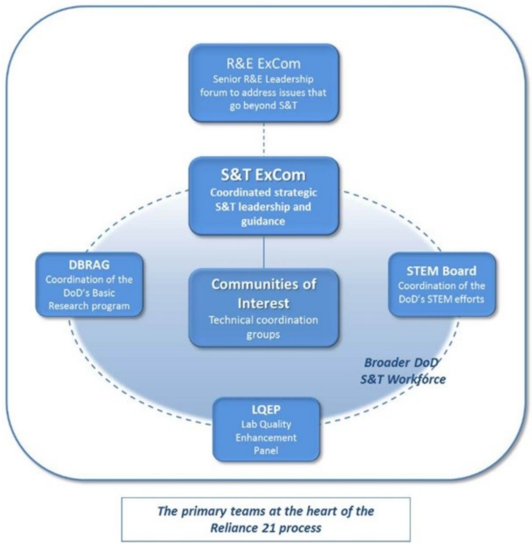

FIGURE 2-5 R&E EXCOM oversight structure. SOURCE: Reliance 21. Operating Principles: Bringing Together the DoD Science and Technology Enterprise. Department of Defense. January 2014, p. 3.

Reliance 21 tasks the Communities of Interest with responsibility for developing "strategic plans and roadmaps with a 10 year horizon that capture technical goals and mission impact." Further, COIs are expected to "coordinate international S&T engagement for their technical area, taking Components strategic objectives into account."[40] Opportunities may exist for strengthening linkages between the Reliance 21 framework and the Service S&T components with international activities and inputs.

In October 2011, the committee was briefed by ASD(R&E) on its plans to develop a new international S&T engagement strategy to better leverage global R&D (replacing the 2005 version cited earlier). Several guiding principles of particular relevance to the study's charge were shared with the committee—for example, to support the Components' (Services') efforts in any country where needed at the basic research level, including federated access to research activities; integrate information from OSD and the Components to provide comparative analyses that inform DoD investments and strategic guidance; and ensure that international research activities protect the security of critical U.S. technologies while enhancing access to global developments in basic and applied research.

These principles are consistent with previous chapter text and highlight the need, and the opportunity that exists, for international research cooperation and

[40]Ibid, p. 6.

global S&T engagement. They also reinforce the importance of the Services' international S&T missions, including their overseas presence and activities (e.g., maintaining an awareness of in-country and regional S&T developments and maintaining critical relationships with longstanding and prospective overseas S&T collaborators). Thus, the Services are well positioned to provide valuable input into strategic S&T decision making by OSD. While the anticipated strategy appears to echo this point, the Committee did not have available the updated plan and cannot comment on the adequacy of the approach taken. Fully leveraging the Services' international S&T activities, investments, and knowledge requires from OSD a coordinated strategic approach to global S&T engagement—not only between the Services and OSD, but also between each of the Services.

Finding III

DoD and its Services have in place many mechanisms intended to improve awareness of global advances in science and technology, but existing mechanisms are not well integrated; barriers and impediments to successful implementation exist; and outcomes are not systematically measured to assess effectiveness.

Each of the Services currently has a variety of mechanisms in place for global S&T awareness and engagement—collectively spanning the entire array of mechanisms set forth in Table 1-1. Individual mechanisms range from those that do not require in-person interaction or sharing of information and to those that require collaboration between researchers. At the passive end of the spectrum, the Service field offices conduct literature reviews and assessments of technical fields using traditional measures such as bibliometrics. Higher levels of in-person engagement include informal dialogues at scientific conferences, workshops, university and other S&T-related site visits, and seminars. At the other end of the spectrum are government-to-government agreements for sharing data and information and S&E personnel exchange, collaborative research (with research jointly conducted and researchers funded by their respective countries), and funding for foreign, non-U.S. researchers by the Services (i.e., seed grants). Researchers within each of the Service S&T enterprises (e.g., researchers at each of the Services' laboratories) also have international activities and collaborations. While, collectively, these international activities and collaborative activities enhance the Services' overall awareness of, as well as participation in, the global research landscape, opportunities exist to more effectively coordinate, integrate, and leverage international efforts across the DRE. Discussions with program managers, S&Es, and leadership within various components of the Services (both in the United States and overseas) and at ASD(R&E) suggest that international activities, programs, and collaborations are typically ad hoc and bottom-up (i.e., driven by opportunistic program managers or by enthusiastic non-U.S. researchers).

Coordination across the colocated Service field offices can occur through a number of mechanisms (e.g., cohosting defense staff and S&E personnel exchanges and seminars, informal dialogues between program managers in different Services, and cofunding seed grants to non-U.S. researchers overseas). While these mechanisms do provide logistics and minimal cost-sharing support, they do not sufficiently enable effective cross-Service knowledge exchange among field office program managers. In the United States, sharing[41] of international S&T activities, programs, and knowledge between each of the Service's S&T offices and laboratories also appears to be insufficient and without articulated strategic goals, outcomes, or metrics.

Within each of the Services, strategies for coordinating and leveraging Service-wide international S&T investments and knowledge are not clearly articulated. Noticeably absent are clear reporting protocols between the Service field offices and headquarter offices that address questions such as the following:

- What are, if any, the S&T priorities for international reporting?
- Is reporting focused on engagement, collaboration, or technology assessments?
- How often and in which format should reporting occur?
- Who should receive field S&T assessments?
- What are metrics for successful reporting?

Discussions with researchers at the Service laboratories indicate that DoD's S&Es recognize the critical importance of not only keeping aware of international research advances within their fields but also maintaining relationships with the international research community. Tightened DoD restrictions on conference travel and attendance and security protocols that unnecessarily delay or prevent S&E discussions, visitations, and collaborations are significant barriers for defense engagement of the international research community. Poor connectivity between laboratory researchers and the Services' international S&T offices compounds these challenges and also leads to missed opportunities for the field offices to provide DoD researchers in the United States with insight into global technology developments.

Even if the composite Service S&T enterprise had a coordinated and integrated mechanism for providing cohesive inputs about the global S&T landscape, it is not clear how that information would be synthesized and used as constructive input for OSD-level S&T decision making. In fact, there does not currently appear to be significant connectivity between ASD(R&E) and the international components of the DRE, other than ASD(R&E) liaisons to NATO

[41]Each Service has a data repository used by its international organization, with varying levels of access. For example, the ONR-G knowledge management system is only accessible by ONR personnel, while the Army database resides on AKO (Army Knowledge Online) and is accessible to anyone with a CAC card.

STO, TTCP, and other similar defense S&T fora. While S&T engagement with these particular countries' defense enterprises, which are typically longstanding allies and research collaborators with the United States, are valuable, they do not capture the full spectrum of S&T developments occurring around the world. Thus, the international networks (cultivated and sustained through bottom-up interactions among individual researchers) of DoD's S&E workforce, as well as S&T knowledge among the Services international S&T offices in the United States and overseas, present a valuable opportunity for enhancing DoD-wide global technology awareness. Current reachback from the Services' S&T components to ASD(R&E) is complicated by the number, and overlapping responsibilities, of entities within ASD(R&E) that have international roles and responsibilities, including the Office of Technical Intelligence, the Office of Basic Research, the Office of International Cooperation, DARPA, and liaisons to NATO STO and TTCP

Each of the Service S&T field offices also needs to improve coordination and engagement with DoD's defense attachés posted to U.S. embassies. In each of the countries visited by the committee subgroup, there was limited connectivity and exchange of information between posted defense attachés and the Service field offices. Defense attachés typically have responsibilities for international agreements, treaties, foreign military sales, security training and demonstrations, and managing bilateral and regional defense security relationships, but not necessarily for engaging the in-country or in-region basic research communities (e.g., universities, research institutes, research funding agencies). While their mission is far removed from that of the S&T field offices, for many prospective non-U.S. researchers with interest in defense research collaboration, the embassies' defense science attachés or equivalents are the first point of contact.

Currently, there are a number of barriers and impediments that prevent the DoD from taking full advantage of the opportunities brought about by the globalization of science and technology. For successful improvement of DoD-wide coordination of international activities and knowledge, as well as awareness of global S&T developments, DoD needs to address the following challenges described below.

Each of the Services lack consistent and transparent international S&T knowledge networks both within their own S&T enterprises and across each of the Services. In addition, current DoD approaches for global S&T awareness and engagement do not have clearly articulated objectives, implementation plans to address identified challenges, and metrics for successful outcomes. There are also many missed opportunities for the Services international S&T offices in the United States and overseas to more effectively capture and share information about global S&T. While Service field office staff complete trip and conference reports, the committee heard from researchers in many areas of the DRE that such information is not particularly useful, either because the information is not easily accessible/searchable or because the information does not provide the type of insight researchers want.

Field office staff also share information on an ad hoc basis with program managers at headquarter offices or directly with researchers at DoD laboratories based on their professional scientific networks (e.g., knowing who key players are in particular fields) or past work experience (e.g., formerly working as a program manager at headquarter offices). This mechanism, however, is not sustainable, as program managers rotate frequently and often have limited S&T expertise. Moreover, if program managers are scouting within their own fields, the field office technology scouting missions may run the risk of becoming either too broad or too narrow, thereby missing critical S&T developments. Thus, it would be beneficial for the field offices to establish staffing strategies that consider unique qualifications for foreign posts (e.g., language fluency and cultural awareness) and also balance the needs for "generalists" or "subject matter experts" with specific mission objectives. This is an important aspect of equipping DoD's S&E workforce to more effectively maintain global situational awareness.

2.6 Summary

DoD has many entities with responsibilities and interests in global S&T engagement and awareness, including S&Es at defense laboratories and research centers, program managers and other S&T personnel within the Services' offices of research in the United States and overseas, defense liaisons to international S&T fora such as TTCP and NATO STO, and ASD(R&E) S&T policy and decision makers.

Each of these entities has their own activities for maintaining international S&T awareness and for collaborating, but these activities are not coordinated and valuable S&T knowledge and insight is not aggregated or shared in a form that provides integrated awareness within and between the Service S&T enterprises, and to ASD(R&E). In addition, defense S&Es are often subjected to security provisions that are more appropriate for later stages of development, provisions that hamper their ability to learn from the rest of the world and to develop necessary collaborations.

Given shrinking budgets for international travel and difficulties funding overseas research collaborations, the Services' field offices have a unique opportunity to provide on-the-ground engagement with non-U.S. research communities, as well as to serve as DoD representatives for developing trusted and mutually beneficial collaborative relationships. However, effective reachback mechanisms between field offices and their respective headquarter activities do not exist, which results in missed opportunities to provide value to defense researchers back home and to support the broader DoD mission. While there is significant potential for the defense research enterprise to gain awareness of and leverage global S&T, DoD needs a strategy composed of an integrated suite of approaches that are coordinated both horizontally across the Services and vertically to ASD(R&E).

3

Other Approaches for Global S&T Engagement

"A strategic approach to internationalization and international cooperation should increase coherence, define actions big enough to make a difference and have clear impacts…"[1]

This chapter includes objectives and attributes of other approaches for global S&T engagement used by governments, academia, and industry, as well as descriptions of those organizations' motivators for international engagement. It also explores the implications, both the challenges and opportunities, for the Department of Defense (DoD) to either adopt or leverage these approaches.

3.1 Approaches by Government

Global science and technology (S&T) engagement by U.S. federal agencies yields the greatest returns in instances of shared missions and comparable capabilities, facilitated by trusted channels of communication and information exchange. It has been demonstrated repeatedly over the years that cooperation can exist, and information can be shared at appropriate levels, while retaining, and advancing, uniquely national interests. There are numerous examples of the benefits of international cooperation for U.S. government departments and agencies.

For example, for the U.S. Department of Agriculture (USDA), foreign access and engagement yields valuable information to advance research on agricultural productivity, consumer protection, and wider access to foreign markets. For the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the Department of the Interior (DOI), international and trans-border science programs can bring fresh approaches to

[1]"International Cooperation in Science, Tecchnology and Innovation: Strategies for a Changing World." Report of the Expert Group established to support the further development of an EU international STI cooperation strategy. ISBN 978-92-79-26411-5. Copyright European Union 2012, p. 10.

critical domestic services and help to achieve common understanding and global commitments to sustainable stewardship of the earth and its resources.

For the U.S. Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention (CDC), international science collaboration helps the United States confront diseases where they occur and supports the standards and regulations that ensure the safety, quality, and efficacy of products (produced domestically or abroad) that protect human health and quality of life. For the National Institute of Standards and Technology (NIST), exchanges of scientific information and expertise enhance U.S. technological competitiveness and national security. For the Department of Homeland Security (DHS), international S&T coordination can serve enable and promote global antiterrorism efforts. For the National Aeronautics and Space Administration (NASA), there can be no agenda for research and exploration that does not include the collaborative participation of countries throughout the world.

There is also a significant (and growing) dimension of U.S. engagement in international S&T that is directed toward responding to the vast needs of the developing world. Through the relevant U.S. Agency for International Development (USAID) bureaus, the USAID Office of the Science Advisor, the USAID missions throughout the world, and a network of additional supporting federal agencies and non-governmental organizations, science-based programs are helping developing nations achieve self-sufficiency and improved quality of life for their populations. For other countries, international S&T engagement and cooperation can be a means for several ends, for example, to improve economic and security relationships between countries, to build capacity in countries that are S&T underperformers, to address transnational and global challenges that require international collaboration, and to access the best S&T and S&Es anywhere around the world.

3.1.1 Drivers for International S&T Engagement and Awareness

Agencies and departments throughout the U.S. government recognize that international engagement in S&T will be key to the nation's ability to compete economically, defend national security interests, and tackle some of the most vexing global challenges for populations everywhere. Science diplomacy, specifically the organized efforts of the federal government to engage in scientific and technological collaboration with foreign counterparts, is a vital component of America's foreign policy agenda.

While the United States continues to lead in research productivity, there is a marked increase in publications, patents, leading-edge discoveries, and professional and academic exchanges among other countries, including in the developing world. Access to, and engagement with, these foreign assets is essential for the U.S. to remain a player in all critical domains and to avoid technological surprise. The principal objectives for international scientific engagement generally fall into three broad categories:

- To accelerate the pace and the delivery of research and development (R&D) for U.S. interests (civilian and military), avoiding duplication of effort and meeting the considerable costs of large-scale research through the leveraging of international resources;
- To achieve common understanding and application of science-based standards and policies between our countries and collectively in response to wide-ranging global imperatives; and
- To establish the connections, knowledge, and trust that can heighten the prospects for commercial access and the exchange of products and services between the United States and foreign markets.

Within the international research community, there is a wide recognition that the United States S&T enterprise, which includes universities, industries, and government laboratories, continues to maintain strong technological stature in many research fields and scientific disciplines. This, combined with its reputation for scientific integrity, reliable government funding support, and high quality of life, make the United States a very attractive partner for S&T collaboration. Collaboration with the United States provides foreign researchers access to one of the world's largest S&E talent pools; allows for cost sharing and leveraging of resources, infrastructure, and knowledge; and builds connectivity between researchers.

3.1.2 International S&T Engagement and Awareness Approaches

In more than 20 federal agencies (including nearly every cabinet-level department), numerous offices and divisions are assigned the responsibilities to oversee programs of international research and information exchange. In addition, the White House Office of Science and Technology Policy (OSTP), in coordination with the U.S. Department of State, works to enhance international S&T cooperation through joint commission meetings, dialogues, and programs, such as the Science Envoy Program. These federal programs underscore the importance of robust channels of communication, exchange, and collaboration between U.S. government organizations and their foreign counterparts.

While the U.S. requirements for information and access to foreign science and technology are varied, the forms of international scientific engagement have much in common across agencies. They include, for example, joint research programs, professional and academic fellowships and exchanges, data and information exchanges, shared access to observation and data collection platforms, programs for management and enforcement of shared resources, collaborative participation in the programs of wide-ranging global science-based organizations, access to large international research centers and facilities and infrastructure projects, and international funding opportunities.

U.S. government researchers recognize the importance of monitoring their peers on a global scale to maintain awareness of leading international trends within their respective technical fields. International science collaborations in-

volving federal agencies incorporate the principles embraced by scientists for centuries concerning freedom and equity of access to research, with particular attention to serving U.S. national interests and protecting intellectual property. Products of these collaborations often include technical reports, proceedings, and related materials that can be uniquely valuable, as they are designed for specific audiences, often aimed at linking research to applications, and usually available without the delays associated with literature peer reviews.

The United States is currently a signatory to many formal government-to-government agreements in science and technology with countries all over the world. To a large extent, the very decisions of federal agencies to enter into these collaborative science agreements result from securing relevant information concerning comparative foreign assets and the merits of potential partnering opportunities. Conferences, workshops, and literature surveys provide useful insights, but they cannot substitute for S&E exchanges and joint research.

Among federal agencies, the most effective (and most comprehensive) approaches to international S&T collaboration involve routinely updating the protocols that define agency participation in these formal agreements, consistent with changing national research priorities, while maintaining regular, ongoing programs of researcher and student exchange and information sharing. Numerous countries maintain similar S&T government-to-government agreements and memoranda of understanding.[2] The effectiveness of such agreements is dependent on the ability and willingness of agencies to implement the agreements and make sure they are doing meaningful activities. There is a wide array of potential international networks ripe for leveraging by U.S. government agencies seeking international engagement.

Federal agencies (civilian and military) also deploy experts to positions abroad in locations strategic to agency missions, and often with regional responsibilities. For example, the Department of State's Bureau of Oceans and International Environmental and Scientific Affairs (OES) has forward-deployed Environment, Science, Technology, and Health (ESTH) offices[3] in embassies around

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[2]For example, Canada has S&T agreements with China, India, Japan, France, Germany, Russia, Sweden, the United Kingdom, the United States, Brazil, Chile, and Israel (http://www.tradecommissioner.gc.ca/eng/science/agreements.jsp; last accessed on March 31, 2014); Israel has S&T agreements with many countries, including Germany, China, Japan, France, Canada, the United Kingdom, Russia, and the United States (http://most.gov.il/english/international/Pages/default.aspx; last accessed on March 31, 2014); and Australia has S&T agreements with the European Union, France, Germany, Italy, Switzerland, the United Kingdom, China, India, the United States, Canada, Brazil, Japan, Korea, Singapore, Taiwan, New Zealand, and South Africa (http://www.innovation.gov.au/science/internationalcollaboration/Pages/default.aspx; last accessed on March 31, 2014).

[3]The ESTH mission is to engage U.S. allies on OES issues (e.g., oceans and fisheries, conservation), to represent U.S. positions in multilateral fora (e.g., U.S. Mission to the European Union), to work closely with other U.S. government agencies and support their efforts by raising key issues at the diplomatic level, and to cooperate with nongovern-

the world, and the National Science Foundation (NSF) maintains overseas offices in Paris, Beijing, and Tokyo.[4] Reporting and support for agency international programs are among the functions of these positions. Information is shared among these experts in the course of their duties abroad (including between civilian and DoD experts at overseas locations), but this information sharing is often aimed at cultivating contacts more than analyzing foreign S&T enterprise. Genuine mission coordination is, therefore, less frequent across agencies.

The United States is also deeply engaged in fostering the next generation of science and technology leaders through programs such as the Department of State's International Fulbright Science & Technology Award, which has brought more than 200 exceptional students from 73 different countries to the United States to pursue graduate studies in only the last five years. The Department of State also oversees the Jefferson Science Fellows program, in which fellows serve as science and technology advisors on foreign policy issues.

3.1.3 Opportunities and Challenges for the DoD

Many federal agencies have mandates that permit the sharing of scientific information at levels ranging from the most basic research to scientific applications that may simultaneously meet national objectives and serve the common good. The most effective global collaborations are those in which the research priorities are well defined and shared, and include a clear understanding about the breadth and limitations of cooperation.

The DoD has limits on the extent to which some specific information may be shared, but the study committee observes that the basic R&D underpinning many of the 17 technical areas set forth in the Reliance 21 framework is not military specific. Thus, DoD can continue to engage globally in many of the forums employed successfully by other federal agencies. DoD can also benefit greatly from professional and academic fellowships and exchanges that broaden the scope of basic research and add varied perspectives to the core science undertaken in the federal laboratories. Federal agencies assign high trust to their scientists to engage globally while continuing to secure national interests. These scientists are also entrusted to distinguish between research opportunities that advance U.S. objectives and those that lack merit or relevance to U.S. priorities.

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mental organizations to raise awareness of ESTH issues and to strengthen diplomatic relations. OES also maintains 12 regional environmental hubs at embassies around the world to address transboundary environment through regional cooperation. Regional hub officers seek to promote environmental cooperation, sharing of environmental data, and adoption of sound policies that will benefit all countries in that area.

[4]The International Science and Engineering (ISE) section of NSF is responsible for international collaborative activities across NSF and co-funds awards and supplements in cooperation with NSF's disciplinary directorates. The mission of the ISE overseas offices is to promote international collaboration, serve as a liaison between NSF and its overseas counterparts, and report on developments in the international science and engineering community.

Federal researchers cannot be expected to deliver on these goals absent the chances to explore the global research landscape through access to conferences, workshops, and other traditional forms of information exchange.

DoD researchers are no exception in this regard, whether in terms of the importance of conferring trust or the need for current access to global science. Global engagement brings with it scientific credibility that is, in turn, critical to attracting scientific information that can ultimately serve the U.S. interest. The opportunities are admittedly fewer for DoD researchers to engage in joint research programs or even to share access to observation and data collection platforms. The costs and complexities of large-scale programs, especially those that require prohibitively high infrastructure investments, provide valuable opportunities for international collaborations; once approved, every effort should be made to facilitate collaborative research and not to encumber researchers with excessive and restrictive policies and procedures.

DoD representatives in strategic locations abroad still play valuable roles in identifying and directing U.S. researchers toward significant foreign assets. With an increasing blend of objectives and capabilities between the civilian and military sectors, coordination of information collection is all the more essential. The ongoing growth and access to open-source science information will require a sharpened focus on what appropriate methodology and reporting requirements should be used by federal agencies. Today, the most valuable information is often that which characterizes the context or the institutional framework in which research and technological advancements are occurring abroad; this adds an important dimension to material readily identifiable in the public domain.

Considerably less effort has been devoted to comparative analysis of international missions or coordinated analysis of collected information. There is an ever-growing need for an organized effort across the federal government to share mission objectives and to identify areas of overlap, synergistic support, and gaps. Opportunities to share and support missions need to be incorporated into practice, including coordination of follow-up analyses.

3.2 Approaches by Academia

The increase in connections among different nations and societies that the world has witnessed in recent years, fostered in part by rapid advancements in communication technologies during the late 20th century and by the widespread dispersion of economic growth across the globe, has had a profound impact on social, economic, and intellectual exchange. Both developed and developing nations share a growing sense of common global challenges that can be met only through mutual effort and cooperation. As institutions dedicated to education, knowledge advancement and service to society, universities are uniquely positioned to help shape the ways in which these international connections will continue to develop.

Universities are very conscious of the ongoing leveling in science and technology performance throughout the world. Although absolute metrics for

research outcomes, publication citations, and prestigious world prizes in science, engineering, and mathematics remain high for U.S. academic researchers, these metrics in relative terms show steady declines due to increasing investments in higher education and research among all nations of the world. Economists have argued that investments in basic R&D provide powerful engines for economic growth. For this reason, universities around the world, for example those in the BRIC (Brazil, Russia, India, and China) countries, aspire to be ranked among the top one hundred world universities in order to attract top research faculty and students; indications are that they are succeeding (see Figure 1-3c).

3.2.1 Drivers for Global S&T Engagement and Awareness

Research activities at most U.S. research universities are becoming more global for a number of reasons: (a) the faculties include a high percentage of foreign-born researchers, (b) universities receive funding support from foreign-owned businesses that are well established in the United States, (c) universities have substantial numbers of successful alumni in many countries, (d) researchers seek collaborations with top researchers abroad (many among their alumni) in order to track important advances at the frontiers of science and engineering, and (e) universities have an obligation to prepare their students to live and work in a world that is becoming more internationally connected. As a result, every major research university in the United States. has developed some level of strategy for how it will engage with foreign researchers and partner institutions and how it will contribute to intellectually challenging problems worldwide.

Many U.S. universities have a substantial history of international activities related to research and education, and the expanding global connections of the 21st century provide increasing opportunities to engage in projects and collaborations outside of the United States. These opportunities are reflected in part by growing demands in two directions. First, faculty and students have research and educational interests that often naturally lead to international activities and experiences, especially as communication across national boundaries expands, and research and teaching interests overseas increasingly advance to intellectual frontiers and complement the interests of the university. Second, many U.S. universities are widely viewed as high-value partners by foreign governments, corporations, and non-U.S. universities, which increasingly seek to initiate collaborations and share or access resources with the U.S. universities.

Many of the most challenging contemporary problems facing researchers and educators transcend national boundaries (e.g., energy and environment issues). Often the best solutions to these problems are being developed overseas, thus providing universities increasing opportunities for constructive, global engagement in a range of precompetitive research areas. In addition, it is well understood that competition among peer universities will take place increasingly within a global framework and thus a multifaceted approach for global engagement is essential for the proper positioning of the academic institution.

3.2.2 International S&T Engagement and Awareness Approaches

The most successful global engagement by universities strengthens the core mission of education and research of the university. A university's international engagement approaches should satisfy the following outcomes: (Education) to provide its students and faculty with high-quality opportunities to learn about and engage with the world; (Research) to provide its students and faculty with unique and enhanced research opportunities worldwide; (Service) to undertake international service activities that build upon and leverage its strengths and leadership while providing new research and educational opportunities for its faculty, students, and staff; and (Campus Community) to maximize the quality of its educational, research, and service programs by attracting the best faculty and students from around the world.

According to a recent publication from the American Council on Education (ACE), global engagement can arise from bottom-up or top-down strategies and occur at the individual, institutional, or governmental level.[5] At the individual level, many researchers at U.S. universities have small, thematic research-oriented international engagements and collaborations. These collaborations are entrepreneurial in nature, initiated and managed by individual faculty members, and driven by common research interests, alumni networks (e.g., collaborations with former students and postdocs), and a desire to access facilities and infrastructure located abroad. Researcher-to-researcher networks are established through in-person interactions at scientific conferences and professional meetings, visiting faculty seminars, and student and faculty exchanges.

At the institutional level, most U.S. universities are engaged in an ecosystem of educational arrangements (e.g., through memoranda of understanding and joint and dual degree programs) for their students, particularly undergraduate students, to study abroad. In addition, numerous universities around the world have international branch campuses[6] (according to one study,[7] there were 200 international branch campuses around the world by the end of 2011 with more than three dozen scheduled to open within two years). Many research universi-

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[5]Challenges and Opportunities for the Global Engagement of Higher Education . P.P. McGill and R.M. Helms. (originally presented at the Beijing Forum conference on November 1, 2013). The American Council on Education, Center for Internationalization and Global Engagement. Retrieved March 31, 2014, from http://www.acenet.edu/news-room/Documents/CIGE-Insights-2014-Challenges-Opps-Global-Engagement.pdf.

[6]Examples of U.S. research universities with international branch campuses include New York University in China and United Arab Emirates; Syracuse University in Italy, Spain, Chile, England, and China; George Mason University in South Korea; and Carnegie Mellon University in Australia. A more in-depth listing of international branch campuses is provided in Appendix E.

[7]International branch campuses: data and developments. W. Lawton and A. Katsomitros. 2012. The Observatory on Borderless Higher Education. Abstract retrieved March 31, 2014 from http://www.obhe.ac.uk/documents/view_details?id=894.

ties also maintain centers overseas,[8] co-brand or operate collaboratively with overseas institutions,[9] or manage foreign international universities in order to expand the global reach for their faculty and students.

Government policies and programs can also be used to support university global engagement practices—for example, the Erasmus programme encourages cooperation between higher education institutions and supports cross-border student mobility in Europe. Launched by the European Commission in 1986, Erasmus has enabled more than 2.2 million students and 250,000 university staff to be mobile within Europe (approximately 90% of higher education institutions in 33 European countries take part in the program).[10]

Bilateral S&T agreements, memoranda of understanding, and cooperation programs between institutions and/or governments are also used to facilitate international engagement by and among academic institutions. One example at the governmental level is the U.S. NSF Partnerships for International Research and Education (PIRE), which supports projects that require international collaboration (in 2012, the PIRE program supported 12 projects with participation by 28 total countries[11]). Another example is the Innovation China–UK (ICUK) program, established through joint funding from the Higher Education Funding Council for England, Department for Innovation, Universities & Skills (now Department for Business, Innovation & Skills) and the Chinese Ministry of Science and Technology to promote joint innovation and knowledge transfer. Since its launch in 2007, the ICUK has funded 72 collaborative technology projects and engaged more than 270 academics from China and the United Kingdom.[12]

Universities can also be tasked to execute bilateral governmental research S&T cooperation programs. For example, the Swiss Confederation has bilateral research cooperation programs with India, Brazil, Chile, Russia, South Africa, China, South Korea, Japan, and Vietnam; Ecole Polytechnique Federale de Lausanne (EPFL) has responsibility for promoting and strengthening collaboration

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[8]For example, Columbia University's Global Centers in Kenya, China, France, Turkey, Brazil, Chile, Jordan, and India.

[9]For example, Yale University–National University of Singapore College; Skolkovo Institute of Science and Technology established in collaboration with Massachusetts Institute of Technology, Duke Kushnan University established in partnership between Duke University and Wuhan University, and a joint institute between the University of Michigan and Shanghai Jiao Tong University.

[10]Available at http://www.aef-europe.be/documents/Improving_the_participation_in_the_erasmus_programme.pdf. Last accessed on March 31, 2014.

[11]Argentina, Australia, Bangladesh, Belgium, Belize, Brazil, Cameroon, China, Czech Republic, Denmark, France, Gabon, Germany, India, Indonesia, Ireland, Italy, Japan, Mexico, Netherlands, Russia, Singapore, Spain, Switzerland, Turkey, the United Kingdom, and the United States. http://www.nsf.gov/od/iia/ise/pire-2012-list.jsp. Last accessed on March 31, 2014.

[12]Available at http://www.icukonline.org/about/phase1.shtml. Last accessed on March 31, 2014.

with four of these partner countries (ETH Zurich, the University of Geneva, and the University of Basel manage the other five partner countries).

In addition to bilateral cooperation, many universities also participate in multilateral and global research collaboratives and worldwide research projects. For example, the King Abdullah University of Science and Technology (KAUST) Global Collaborative Research (GCR) creates and supports an international community of academic researchers to collaboratively solve global technological problems. Other examples of large global research collaboratives and consortia include the following:

- The European Organization for Nuclear Research (CERN) is a fundamental physics research organization with 21 member states. More than 600 institutes and universities around the world use CERN facilities with approximately 10,000 visiting scientists from 113 countries.[13]
- The European Molecular Biology Laboratory (EMBL) is a public molecular biology research organization funded by 20 member states. EMBL has five sites across Europe; research is conducted by 85 independent groups across 60 nations.
- The Integrated Ocean Drilling Program (IODP) is an international marine research program that brings together researchers from universities and institutes around the world; the United States and Japan are formal lead agencies, and there are 17 contributing country members and 3 associate country members.
- The Square Kilometre Array (SKA) Project is a global collaboration to build a radio telescope with a collecting area of one million square meters. The SKA organization has 10 country members and 1 associate country member, with 100 organizations across 20 countries participating in the design and development of the SKA.
- The International Geosphere–Biosphere Programme (IGBP) coordinates international research on global- and regional-scale interactions between Earth's biological, chemical and physical processes and their interactions with human systems through a coordinated network of more than 50 national and scientific committees and international project offices.

Industry can also play a role in supporting international engagement and collaboration efforts for universities (between universities and between industries and universities). For example, the Intel Science and Technology Centers (ISTCs) and Intel International Collaborative Research Institute (ICRI) fund jointly led research collaborations between Intel and the international academic community.

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[13]Available at http://home.web.cern.ch/about/member-states. Last accessed on March 31, 2014.

As another means of maintaining awareness of global advances in S&T, some university researchers are developing methods to retrieve, synthesize, and identify relevant patterns from open, worldwide data sources. Such research employs the Internet for sharing data, publications, and courseware and conducting cooperative experiments and simulations on globally connected user networks (e.g., the HubZero[14] tool developed at Purdue University).

For each of those engagement activities and approaches, it is also important to identify factors that can contribute to less successful outcomes. For example, not paying enough attention to political and social sensitivities abroad, not having enough faculty engagement from the home university, and not paying enough attention to being economically and intellectually sustainable illustrate some considerations that should be taken into account when developing any approach for international engagement.

While a universal best strategy for global university engagement has not yet emerged, it is clear that increasing mobility of the global S&E workforce, as well as increasing public and private research investments made around the world, are motivating universities to take a strategic approach to international engagement and collaboration to remain among the world's best institutions—and likely will continue to do so.

3.2.3 Opportunities and Challenges for the DoD

These dynamic movements in U.S. universities, spurred in large part by growing international competition, represent opportunities for defense agencies to achieve more timely access to advances in science and technology throughout the world. This will generally require strategies to strengthen the coupling of government researchers with leading academic researchers and to improve access to their top students for employment (one best practice for technology transfer). Strengthened defense-academic coupling can provide broadened S&T inputs to improve defense roadmaps for staying at the cutting edge of materiel modernization and force readiness.

There are also opportunities for the DoD to adopt and leverage the international engagement activities and programs of academia. In addition to leveraging international networks that exist due to collaborative research, DoD could take advantage of open innovation approaches being developed by university researchers that seek to leverage the Internet, other open global data sources, and collective idea sharing. These efforts should be coordinated with the Defense Advanced Research Agency (DARPA), defense contractors, and other global enterprises, which are already engaged in these activities. These collective capabilities represent excellent opportunities for defense agencies to tap into early technological developments on a global scale.

The DoD could also identify opportunities to better synchronize technology transfer from universities, government laboratories, and the private sector to

[14]Available at http://hubzero.org/. Last accessed on April 8, 2014.

close the gap between product development and commercial scale-up. This is especially important as the DoD relies increasingly on rapid adoption of technologies stemming from R&D investments made by others. Technology transfer will increasingly require a global perspective and closer partnerships among foreign industries, universities, and governments. As such, the DoD should consider engaging with overseas research institutes (e.g., Battelle Memorial Institute, Fraunhofer Society, and Industrial Technology Research Institute [ITRI]) that develop innovative products and services for clients on a global scale and have a successful track record of technology transfer. These types of research institutes have strong relationships with international universities, private companies, and government research laboratories (both civilian and defense) that can also be leveraged through collaboration.

There are also opportunities to establish partnerships with U.S. academic researchers who are internationally engaged in strategic, defense-related research and can advise on international SWOT (Strengths, Weaknesses, Opportunities, and Threats) issues; many of these researchers are already supported by the Service offices of research. The DoD should engage this community and provide opportunities for these researchers at universities to engage with the defense research community and, possibly, to provide briefs on relevant international research conferences they attend and on important technological developments abroad. This can stretch limited travel resources for government employees, as U.S. researchers are already attending such conferences. Developing such a relationship between academic researchers and defense researchers (and decision makers) will require the DoD to establish clear open-access, basic research boundaries and incentives for civilian researchers in the United States to engage with members of the defense research community.

The DoD could also consider designing “in-place” internships to engage top university students in basic research projects with downstream defense applications. These internships would allow undergraduate students to carry out unclassified projects on campus during the academic year as full members of defense laboratory teams and be sustained over the summer break by residence in a defense research center. The strategy would not only aid in the transfer of technology, but also promote recruitment. Ideally, these projects would be globally leveraged through international collaborations.

3.3 Approaches by Industry

An evaluation of the wide range of technology collaboration models utilized by global industry and implications for the U.S. DoD would be incomplete without first establishing the fact that the mission, motivations, and objectives of the DoD and industry are markedly different. The analysis presented below will identify areas in which the two groups align and diverge. Where divergence is present, an attempt to draw parallels between the objectives of the groups will be offered.

3.3.1 Drivers for Global S&T Investment by Industry

Areas of technology addressed by industry in a global collaboration setting are influenced not only by the needs of industry but also by export-import regulations, tax laws, and the ability to effectively protect and control intellectual property. Considering the defense-oriented mission of the DoD, a relatively narrow set of collaboration topics and partners are available in comparison to industry.

Global S&T investment by industry takes many forms, but three key drivers are typically involved: (1) a desire to access the best technology and technologists in the world, (2) reduce technology investment costs by coinvesting with others, and (3) using technology investment to strengthen the company's presence and products in key markets.

Technology sourcing – The ability to reach out globally to access the best and brightest has been greatly facilitated through global connectivity advances that allow sharing of massive amounts of information and inexpensive connection by computer, phone, and video over great distances. The barrier to entry for basic tools of innovation (a computer connected to the Internet) have been lowered to the point that it is no longer the more advanced economies of the world that are producing innovative ideas. Brilliant people can show up anywhere on the planet and the chance of them gaining access to a computer to educate themselves and connect to the rest of the world is growing daily. With these trends in mind, it makes sense that industry is increasingly looking outward to find the best technologies and technologists.[15]

Reducing R&D costs – The pace of technology advances continues to accelerate and the cost for a company to independently invest enough resources in technology to maintain a competitive advantage can be prohibitive. Meanwhile, customers have grown accustomed to purchasing more capable products at lower prices and have a built-in expectation of more for less. Even through the recent challenging economic times, global technology investment has remained strong with $1.6 trillion in technology invested in 2013.[16] With this level of technology investment, surely other organizations are trying to solve similar problems. Progressive companies have dedicated teams working to understand who in the world is working on technologies of interest to their companies and then reaching out to them to strike a business arrangement to co-invest and share the results. At times this can take the form of an industry standards group where financial resources and know-how are pooled to drive creation of standards and perhaps new technol-

[15]Committee members visited several foreign-owned corporations (see Appendix A) and heard about a variety of strategy-directed mechanisms. This was in contrast to most university and government organizations visited which tended to rely more on researcher-to-researcher networks to maintain awareness of the "best" research and researchers.

[16]2014 Global R&D Funding Forecast. R&D Magazine and Battelle. December 2013. www.rdmag.com.

ogies that will benefit all involved.[17] Sometimes this type of collaboration will be within a supply chain—a supplier and customer co-investing to develop a new innovation that advantages both of them in the market for less overall investment. Finally, cross-sector collaboration is on the rise since it allows development and sharing of technology solutions between companies that do not compete. Whatever forms the co-investment takes, the objective is the same, develop the technology needed for business success at a lower cost.

Market access – The level of investment required to establish a technology presence in a country is relatively modest in comparison to the investment required to establish a business presence and/or production capabilities. As such, industry often leads with technology investment in various forms as a precursor to more significant investment. For some companies, servicing a market cannot be considered without local manufacturing operations, since the nature of the product may not lend itself to being shipped. Other industries may have products that ship easily but need to be tailored for the particular needs of a market. Finally, other industries may have products that remain relatively standard across the globe, but to be successful in selling that product in a particular market, having a local presence of some type helps. Market access requirements vary across industries, but often technology investment can facilitate successful market entry and growth. For products manufactured locally, there is a need to invest in improved manufacturing processes and methods to increase productivity. For products that need to be tailored for a market, investment in local business and technical talent is required in order to shape the product to be successful in that market. Finally, even if a product remains standard in most markets, technology investment by the company that is selling into a market can help satisfy formal or information investment expectations of the local government or business partners.

3.3.2 International S&T Engagement and Awareness Approaches

A range of technology collaboration models are utilized by industry depending upon the end objective and the need to control the contributed and resulting intellectual property. (1) Bilateral research allows for tighter control of intellectual property and highly focused outcomes, since only two parties are involved. (2) Collaborative networks bring medium to large groups of organizations together for mutual benefit, with the network acting as a starting point for project development that may take the form of a bilateral research agreement between two members or a collaboration agreement between a larger group of members. (3) Finally, the R&D consortium in its many forms typically is best suited for addressing common technical challenges in a particular technical area where it makes good business sense for members of that industry to combine

[17]Committee members heard from Ericsson in Sweden an example of a precompetitive collaborative project intended to drive subsequent standards development.

their resources to solve their common problems in a precompetitive setting. Each of these models has its benefits and limitations and is described in greater detail below.

Bilateral research – Searching the world for a collaboration partner that is willing to co-invest to solve a mutual problem can be a daunting task. Some companies are successful in identifying bi-lateral technology collaboration opportunities in their supply chain. These partnerships can yield results, but care must be taken to navigate at times difficult intellectual property issues, since the supplier in the relationship may want to utilize the codeveloped intellectual property with other customers. Similarly, the customer in the bi-lateral collaboration will want to control the sharing of the codeveloped intellectual property with their competitors. Since technology innovation and the competitive advantage it provides tends to fade over time, a potential solution to these conflicting objectives is to define some period of exclusivity for the customer use of the technology. This arrangement allows the customer in the partnership to justify their investment, since it may give them an advantage over their competition for some period of time. Likewise, the supplier in the relationship can justify their investment, since at some point they will be able to use the innovation to differentiate themselves in the market in comparison to their competition. While bilateral collaboration partners may be readily available in a company's supply chain, these intellectual property challenges can sometimes limit the resulting benefits or make structuring of the relationship cumbersome.

Identifying viable bilateral collaboration partners in other industry sectors is a more difficult task; however, the elimination of competitive issues described above can accelerate the ability to quickly move to an agreement and get to work. Significant cross-sector collaboration has occurred between technology-heavy industries such as aerospace, automotive, and energy. Natural alignment of technology needs occur, since many of the same issues are present, for example, the common need between aerospace and automotive for higher-performance, lighter-weight materials for increased fuel efficiency. Likewise, energy and aerospace companies need materials that can perform and survive in extremely harsh environments. Finding these common needs is key to successfully structuring cross-sector bilateral technology collaboration relationships.

Collaborative networks – collaborative networks can facilitate cross-sector collaboration and also act as an avenue to extract emerging technologies from university and start-up companies. The members of the network are bound by a general nondisclosure agreement that the information shared inside the network remains in the network. This allows the sharing of technology needs by the members seeking technology and the sharing of proposed solutions by the technology providers in the network. When a match is identified, the collaboration that results typically takes place under a bilateral or multilateral agreement.

R&D consortium – The R&D consortium model has proven to be well suited to bridging the gap between lower technology readiness level (TRL)

R&D performed by universities and the higher TRL technologies required by industry to incorporate into their products.[18, 19] The model comes in many forms but they all have some common characteristics regarding their technical and financial approach, participants, and intellectual property model.

- Participants – With the focus on bridging the gap between university R&D and industry needs, the typical R&D consortium participants are members of industry, a host university and regional or national government agencies. Industry participation often starts with a small group of launch members that establish the technical focus and master research agreement with the university. The host university plays an important role as the central organizing body for the R&D consortium (e.g., collecting membership fees, performing R&D, growing industry membership and pursuing government grants). Supporting government agencies vary, but are typically biased towards the promotion of trade and industry versus pure scientific research.
- Technical approach – Industry needs drive the process of defining the technical approach. There is a natural tension between the mission of a university to perform and publish basic and basic and applied research and industry's desire to invest in higher TRL-level technology work that will quickly transition to their products and services. In order to satisfy both objectives, research should address real-world industry problems, but the approach to solving these problems should be underpinned by solid theoretical work at the university.
- Financial approach – Financial contributions from all the participants is important to the successful launch, growth and sustainment of an R&D consortium. A tiered fee-based membership is utilized to allow larger companies to pay more per year and have stronger influence in the technical direction. Smaller companies can pay less and have less influence over the technical direction; however, many of the participating smaller companies are suppliers of the larger companies, so a major benefit to them is to better understand the technical needs of their customers and work in partnership to solve their problems. Government support of the R&D consortium usually comes in the form of matching grants against industry financial contributions. Often these grants are focused on establishing the required infrastructure to create an applied

[18]Technology and Innovation Centres. House of Commons Science and Technology Committee. Second Report of Session 2010–11. Volume I. HC 619. Published on February 17, 2011 by authority of the House of Commons. London: The Stationery Office Limited.

[19]"The current and future role of technology and innovation centers in the UK." H. Hauser. A report commissioned by the UK Department for Business Innovation & Skills. Retrieved online April 4, 2014, from http://www.bis.gov.uk/assets/biscore/innovation/docs/10-843-role-of-technology-innovation-centres-hauser-review.

research operation (production quality facilities, equipment, and staff). Financial contributions by the host university are usually in the form of in-kind contributions, for example, contributing university facilities or accounting, financial, and legal services to support the R&D consortium. This pooled financial investment by industry, academia and government provides a highly attractive R&D environment, where, for a relatively modest annual contribution, an industry participant can realize many times their annual fees in R&D work performed.

- Intellectual property model – A two-tier intellectual property model is utilized. Annual fees from industry participants usually go into a general pool of R&D funds that creates a body of precompetitive intellectual property that is owned by the university and is licensed to the members of the consortium—royalty free for top-tier members with various approaches for lower-tier members. In order to transition technology to the products and services of the industry members, special projects can be defined that perform R&D that is closer to their products. Additional financial contributions are made to sponsor these special projects, and intellectual property terms are established to protect the competitive position of the sponsoring industry member.

Success for industry and DoD are defined differently, but for international technology investment there are enablers of success that are common to both organizations including the following:

Driving a culture that values external ideas and capabilities – A first step in facilitating the successful growth of international technology investment for an organization is to accept that no single organization can possess all the world's best capabilities. This is difficult for many organizations to do, and while the DoD has demonstrated a willingness to invest externally on domestic soil, shifting to a global perspective of external investment will help to capture the wealth of capabilities available beyond U.S. borders. In general, industry has come to this realization but with the long history of DoD technology domination, this cultural shift will be challenging.

Assuring global technology investment plans are an integral part of a broader technology investment strategy – A common misstep in global technology investment planning is to frame international technology investment as special or extraordinary in some way, warranting a different set of metrics and motivators. Unless international technology investments are integrated into an organization's broader technology strategy, they will remain marginalized and their ability to significantly impact the success of the organization will be limited.

Avoiding viewing international technology engagement as a perk – In the past, when organizations could succeed with primarily an inward focus, individuals who engaged in global technology outreach were often cast in a negative light—with the assumption being they were more interested in international travel than a broader mission of technology excellence. With the mandate for

successful organizations to be externally focused, the outmoded idea of international technology being a perk should be eliminated. If the international engagement is in line with the broader strategy of the organization it should be viewed as necessary and of high importance.

Guarding against protecting the base – As organizations transition to a more external and international investment profile, traditional organizational structures and staffing strategies need to change in kind. These changes can be viewed as a threat to the existing staff of the organization, resulting in investment decisions that protect headcount instead of making the sometimes difficult decision to reduce internal headcount in exchange for expanding international technology engagement and sourcing. Organizations that have made the transition to a more global technology footprint have made these hard decisions and suffered through the turbulence the new direction creates.

3.3.3 Opportunities and Challenges for the DoD

If DoD adopts industry practices for global technology engagement, many of the same challenges faced by industry will emerge. Learning from industry's experience in globalizing as DoD sets its plans will be a key enabler of success:

Drive a series of small changes in line with a long-term strategy – Like many large industrial organizations, the DoD is a large operation and change takes time. One potential path to successfully transitioning DoD to a more global technology footprint is to define a longterm vision and implement a series of small changes over time in order to drive to the new state.

Measure of success and reward system – Even small-scale change is difficult if the reward system is not structured to encourage individuals to think more globally. Putting the right metrics and reward system in place is a necessary first step to drive the desired change to more global thinking.

Focusing on key allies as a starting point – Global technology outreach requires a high level of trust with your selected partners. The DoD has long-term allies where this trust exists and relationships that are ready-made to expand global technology engagement. Exercising new engagement models with familiar and trusted partners could facilitate a strong start.

3.4 Summary

International S&T engagement is important for researchers to stay abreast of the state of the art in their fields, to share best practices, and to leverage others' investments and knowledge. Global technology awareness is critical for decision makers—whether in academia, industry or government—to make strategic S&T investments and sound policies for international engagement, economic competitiveness, and national security.

Finding IV

The committee did not identify a single "best" approach to maintaining global S&T awareness, but rather believes an integrated suite of methodologies—spanning the spectrum from passive to active as indicated in Table 1-1—is needed. Opportunities exist for DoD to adopt or adapt practices in use by other institutions and sectors as it implements its strategy to maintain awareness of global advances in science and technology.

Mechanisms for global S&T engagement and awareness used by academia, industry, and government range from passive and requiring little to no human-to-human interaction (e.g., literature scanning and analytical bibliometric techniques) to in-person dialogues and knowledge exchange (e.g., conferences and workshops) to research collaboration and personnel exchanges. None of these mechanisms in isolation suffices. For example, publications and bibliometric analyses represent only a slice of ongoing research and do not necessarily capture the leading edge due to the lag between discovery and publication. Similarly, while attending workshops and conferences provides access to a large community of researchers, awareness tends to be serendipitous and without strategy.

In order to provide enterprise-wide insight into global S&T advances and to inform strategic decision making, each of the above mechanisms should be coordinated organization-wide and the outputs of those activities (e.g., technology papers, notes, reports, data visuals) should be accessible to all relevant S&Es across the enterprises. In addition, there should be an ongoing forum for those S&Es and all entities with explicit responsibility for international S&T (including forward-deployed personnel) that allows researchers to communicate their needs and to provide feedback loops to improve data gathering. Finally, international S&T knowledge and insight from throughout the organization should be integrated and synthesized in a useful form to inform senior-level decision makers. The entities responsible for aggregating and analyzing these inputs need to have an ongoing dialogue with senior S&T decision makers to (a) communicate top-down technology and policy priorities to inform international engagement strategies and (b) provide bottom-up insight on global S&T trends, field assessments of the state of the art in critical technology areas, as well as any cultural and geopolitical factors that could impact technological competitiveness (and for DoD, national security).

Current DoD approaches to exploit global S&T advances, both through awareness and engagement, include relying on the DoD S&T workforce (both at Service laboratories and DoD research centers) and program managers at defense funding agencies to know what the best research is and where it is occurring; S&E exchanges and visits with defense allies; forward-deployed offices and personnel to scout for the best technology; and bi- and multilateral cooperation agreements for joint research. While these sources all provide valuable input, they also face several shortcomings. First, most researchers' awareness

comes from publications (which paint a partial and delayed picture) and through their scientific networks (which are often closed or tightly tethered networks). In addition, researcher bias can create blinders. Second, defense research accounts for an ever-decreasing fraction of the global S&T output; furthermore, there are many S&T fields for which the cutting edge will not be driven by defense research. Thus, S&E exchanges and collaborations need to occur through both defense and civilian (potentially including nontraditional allies) channels. Lastly, DoD currently operates under the premise that its S&Es, program managers, and S&T policy makers have sufficient connectivity to (a) maintain awareness of emerging S&T advances around the world and (b) ensure that such global awareness informs strategic S&T decision making. However, based on committee discussions and visits with various DoD offices and staff, there appears to be limited connectivity between those entities tasked with explicit responsibility for international S&T and with the general DoD S&T workforce and DoD S&T policy makers.

During visits to overseas S&T organizations, several themes emerged that may also provide insights into how DoD might improve its international S&T engagement approaches:

Support and encouragement of international S&T engagement by senior-level policy makers is critical – In each of the countries visited, there was widespread acknowledgment by leadership and/or senior policy officials across academia, industry, and government that international S&T collaboration is important. An increasing global need to share resources and leverage investments was emphasized as a significant driver for S&T collaboration. According to the Australian Academy of Sciences, collaboration not only allows sharing of resources and infrastructures, but also of risk, which leads to better outcomes for all stakeholders. While acknowledging that one industry or nation cannot do everything alone can be difficult, Taiwan's Ministry of Economic Affairs (MOEA) and ITRI noted that exposing one's own strengths and weaknesses often has the result of bringing potential partners to the table.[20] Meetings with university administrators and industry executives revealed that industries became global decades ago and that universities are now in the process of following suit.

Tools for communicating that international engagement is important across an organization include: national S&T strategies and plans that prioritize international engagement, education and immigration policies that encourage global talent migration, federal research funding support of international collaboration, and visibility of leading international researchers and technology and innovation experts as leaders at universities and industries.

[20]For example, ITRI's collaboration with TNO (Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek) in the 3D Printing Technology International Alliance leverages each's respective strengths in 3D metal printing and precision machinery.

Industries and universities have different motivations for international collaboration – Academic researchers seek collaboration with the best researchers, regardless of where they are. Universities seek linkages with other universities to promote international knowledge exchange and to leverage others' investments and infrastructure. As universities are heavily reliant on government support for research, they maintain strong linkages with government funding agencies. In contrast, industry is driven by business factors—seeking to increase the value of and market for its products, reducing costs, improving workforce capabilities, etc. Industries are open to R&D collaborations that have potential to increase new ideas, expertise, and a pipeline of talent.

Country-level (and even institutional-level) strategies are important for building international S&T collaborations – While each of the Services' S&T field offices highlighted building international relationships as a primary objective, there did not appear to be a strategic approach for identifying the most opportune countries and institutions for collaboration. Numerous factors shape the type, and quality, of S&T relationships countries have with one another, for example, concerns related to national and regional security, economic competitiveness, and the desire to absorb foreign talent pools and leverage foreign S&T developments. Country-specific strategies also should consider whether countries are overperformers or underperformers in S&T areas targeted for collaboration. For example, Australia's former Chief Scientist, Ian Chubb, suggested that strengthening relationships with countries that are S&T underperformers today (e.g., through research and infrastructure support) will set in place important long-term relationships that will be critical for future collaboration with that country as its S&T capabilities improve. For countries that are S&T overperformers, opportunities may exist to collaborate in precompetitive areas, such as in standardization. Lastly, country-specific strategies may need to evolve over time, in particular, countries with rapidly emerging economies. For example, in certain areas of U.S.-Thai S&T cooperation, the role of the United States is evolving from being predominantly a capacity builder to a peer-partnership model. In Asia, international collaboration is often driven by shared cultural norms, languages, and societal challenges. The committee noted the growing role that ASEAN (Association of South East Asian Nations) is playing in setting future S&T collaboration goals and agendas in southeast Asia.[21] Understanding those enablers of successful longstanding, as well as emerging, collaborations between Asian nations can provide lessons for the U.S. defense research enterprise (DRE) as it strives to become a better S&T collaborator in Asia. Given the numerous scientific, cultural, historical, and geopolitical factors that impact S&T relationships between countries, it would be beneficial for the DoD to develop country-specific strategies for prioritizing engagement and collaboration activities.

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[21]There are current efforts to develop the STI ASEAN Action Plan of Science and Technology 2015-2020, which will look at country-specific roles in science, technology, and innovation.

Enterprise-wide global S&T awareness begins with ensuring a globally aware S&T workforce – Workforce exposure to the international S&T community can occur through academic networks, participation at international S&T conferences and workshops, or by maintaining an ongoing presence overseas.

Many of the organizations visited by the committee highlighted the strengths of universities in establishing strong international linkages (e.g., through scientific conferences and meetings, collaborative research, student and postdoc exchanges) and noted that these linkages occur regardless of top-down support. Faculty from Australian National University noted that universities rely on their own researchers to know what and where the best research is occurring globally; thus, it is critical to encourage researchers to establish international networks. Taiwan's National Research Council echoed this message, indicating that while it can create opportunities for seminars and visits (through top-down funding support), it is ultimately the responsibility of researchers to promote knowledge exchange and to establish mutually beneficial relationships.

These networks are most successful when they are supported by ongoing opportunities for in-person interaction at hosted research seminars, international S&E exchanges, scientific conferences, workshops and meetings, and trade shows. Conference attendance is highly encouraged both in academia and industry. ITRI emphasized the value of international conferences and trade shows as a mechanism for researchers to both gauge the current state of the art in their fields and to share technology awareness with colleagues. According to IBM Research–Tokyo, in addition to international conference attendance, actual overseas research experience can provide a broader international perspective. Many overseas organizations, such as the Australian Research Council, have programs[22] that provide support for such overseas research experiences. Thailand and Sweden also have government initiatives to encourage global talent migration, not only of their S&T workforce but also to recruit and retain the best researchers.

In addition to ad hoc or limited engagements, many S&T organizations maintain offices overseas, such as the Japan Society for the Promotion of Sciences (JSPS),[23] ITRI,[24] Taiwan's National Science Council,[25] Thailand's Ministry of Science and Technology,[26] Denmark's Innovation Centres,[27] Australia's

[22]"Future Fellowships" and "Discovery Early Career Research Awards" are two such support schemes aimed to attract the best early- and mid-career researchers to Australia.

[23]JSPS currently has overseas offices in London, Stockholm, Bonn, Strasbourg, Nairobi, Cairo, Bangkok, Beijing, Tokyo, Washington, DC, and San Francisco.

[24]ITRI currently has overseas offices in San Jose, California; Berlin, Germany; Moscow, Russia; and Tokyo, Japan.

[25]The NSC currently has 16 overseas offices that are tasked with establishing overseas relationships and identifying good researchers and opportunities for collaboration with overseas universities.

[26]Thailand's Ministry of Science and Technology (MOST) has offices in Brussels, Beijing, and Washington, DC.

Defence Science and Technology Organisation (DSTO),[28] and Sweden's Agency for Growth Policy Analysis.[29] In general, these offices share many similar functions, such as serving as liaisons with overseas counterparts, networking and supporting overseas activities of their home organizations, scouting for S&T developments, and identifying opportunities for collaboration. While these overseas offices show varying degrees of connectivity to their home organization and across organizations, they all display elements of coordination and integration worth examination by the DoD and U.S. government S&T organizations. The U.S. component of the U.S.-Thai Armed Forces Research Institute for Medical Sciences (AFRIMS) emphasized that overseas presence alone is not enough to maintain global S&T awareness. Staying at the leading edge and remaining competitive for research funding requires ongoing conference attendance, S&E exchanges, and dialogues with in-country and regional researchers. Equally important are effective reachback mechanisms that enable two-way sharing of information with their home organization. Finally, it is essential that field staff have technical expertise and cultural backgrounds that are well-matched not only to their overseas placement, but also to their home organization. While discussions with industry reveal that, in general, international experience is critical for career development and upward mobility, many DoD staff indicated that overseas posts are not viewed as career enhancing. This attitude is consistent with perceptions that international S&T engagement is a "low priority" for program managers across the Services and reinforces the earlier discussion emphasizing the need for additional support from leadership.

Opportunities exist to be more engaged with other governmental S&T field offices and forward-deployed S&Es and science attachés overseas – For example, the Department of State has Environment, Science, Technology, and Health offices at embassies around the world, and the National Science Foundation has international offices in Tokyo, Paris, and Beijing. The traveling committee subgroup found that there was very little, if any, connectivity between the Service S&T field offices and the ESTH offices in Canberra, London, and Bangkok. There are also many forward-deployed U.S. government researchers and personnel around the world working at foreign universities and research institutes that could provide additional opportunities for engagement and networking. In addition, committee discussions with overseas organizations that also have international field offices (e.g., the U.K.'s Science and Innovation Network, Sweden's Agency for Policy Growth, as well as embassies that have civilian and defense science attachés) reveal overlapping missions and technology awareness objectives. There was little evidence of connectivity between these entities and

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[27]Denmark has Innovation Centres in the United States, Germany, China, Brazil, India, and South Korea.

[28]DSTO has defence attachés posted at Australian embassies in Japan, the United Kingdom, and the United States.

[29]The Swedish Agency for Growth Policy Analysis has offices in Brazil, the United States, China, Japan, and India.

the DoD. In addition, there are opportunities for members of the DRE with international responsibilities and activities to engage with foreign S&T attaches stationed at various embassies in Washington.

Connectivity in S&T is uneven between non-U.S. defense and civil sectors – This is sometimes a result of mismatched S&T investments or focus areas (for example, some countries have very strong civilian research investments in aging and social issues); other times there are historical or cultural barriers. Strong dividing lines between the civilian and defense basic research have made engagement by the Services' field offices in Tokyo with Japan's basic research S&T enterprises difficult. Leveraging between the defense and civil sector is challenging and not common. In other countries, however, strong ties between the defense and civilian R&D communities were evident.

Horizon scanning and foresight activities should be multifaceted and include international inputs – During its overseas visits, the committee learned about national technology scanning efforts in Japan (Center for R&D Strategy under Japan Science and Technology Agency), Australia (the Australian Academy of Sciences has an memorandum of understanding with DSTO to provide some foresight services), and Thailand (APEC Center for Technology Foresight under the National Science Technology and Innovation Policy Office). These programs consisted of global technology surveys, expert panels, and roadmapping exercises with researchers, business representatives, and policy makers. The committee also learned about foresight activities from two Thai industries (Siam Cement Public Company Limited and PTT Public Company Limited) that consisted of a combination of deep publication assessments and IP mapping performed by large technical teams of researchers and technology business consultants. In each of these cases, foresight activities were highly international and, in the case of industry, restricted in technological scope.

Meetings with the Service S&T field offices and laboratories suggest that the primary means of horizon scanning occurs through traditional bibliometrics (e.g., most cited papers, most cited authors, keyword hotspots, patents). This is also the case for briefings provided by the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) on horizon scanning efforts, in which there appeared to be few international inputs (other than foreign language publications). DoD's international S&T activities are a unique opportunity to provide a valuable source of inputs to inform DRE-wide collaboration strategies and S&T trends and investment priorities. Beyond ad hoc technology assessments conducted by Service field office staff, the committee did not hear about any significant Service or ASD(R&E) efforts to coordinate or analyze international S&T inputs from any of the Services' S&T enterprises. In fact, other than input from the Technical Cooperation Program (TTCP) and the north Atlantic Treaty Organization Science and Technology Organization (NATO STO), it is not clear how any of the Services' international S&T activities are informing DoD S&T policies.

Creating international alumnae networks – Many foreign organizations visited by the committee discussed the value of creating and leveraging "alum-

nae networks" of researchers and S&T professionals that have experience working internationally. In some cases, members of these networks have returned home after working overseas and others are now expatriates in other countries. This is an interesting model that DoD might consider, that is, leveraging alumnae networks of DoD S&Es and program managers with international experience, whether through international collaborations and professional networks, field experience at the Services S&T offices, or through international S&E exchanges. Such networks could be useful resources to get the benefit of individual knowledge or of the group as a whole. These networks should be tracked and analyzed over time for trends to assess the health of DoD's international collaborations and S&T workforce. Organizations like JSPS make impressive efforts to monitor trends in S&E exchanges between Japan and other countries. These data could provide interesting insight when correlated against other factors, such as differences between countries' S&T policies and budgets, economies, and other cultural and geopolitical considerations.

The outcomes of international S&T engagement and collaboration activities should be evaluated against success metrics – This is standard practice in the private sector, where the bottom-line driver provides clear motivation. Box 3-1 summarizes key factors used by IBM Tokyo, for example. Based on the committee's discussions with other governmental organizations, the use of such success criteria is uneven. Those organizations whose motivation is to generate economic value through S&T investment tend to measure outcomes at some level, whereas those whose motivation is "public good" tend to focus on input measures. An Expert Group established to help the European Union set priorities for international collaboration identified four considerations: (1) cooperation can increase the world's ability to tackle global challenges; (2) complementary scientific and innovative strengths lie outside the European Union; (3) there are important gaps in European competences; (4) cooperation can increase access to global markets and infrastructures.[30] The group asserts the "need for an evidence and analysis-based strategy" and identifies a comprehensive array of indicators that could inform decision making.[31]

In spite of advance requests to DoD briefers, the committee did not hear about effective metrics being used to measure international S&T engagement outcomes at any of the organizations visits, including from ASD(R&E), DoD laboratories, and Services S&T offices in the United States and overseas. While some presentations did share anecdotal success stories, there appears to be no ongoing assessment of the effectiveness (or efficiency) of ongoing international engagement activities.

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[30]"International Cooperation in Science, Technology and Innovation: Strategies for a Changing World." Report of the Expert Group established to support the further development of an EU international STI cooperation strategy. ISBN 978-92-79-26411-5. Copyright European Union 2012, p. 10.

[31]Ibid, p. 53.

BOX 3-1
IBM Research–Tokyo Case Study: Factors for Successful Engagement

A discussion with IBM Research–Tokyo on their criteria for opening a new international R&D center highlighted some key elements of successful engagement. The proposed technology center has to be strategically relevant, the location must have a critical mass of talent, and there needs to be stable and long-term government support for the technology. There also must be openness to partnering along with respect for intellectual property. Although IBM hires in-country, they always place experienced U.S. researchers at the center to provide insight into applications and to provide connectivity with other centers. IBM Research–Tokyo noted that critical mass can provide important input for spotting emerging technology areas ripe for partnership. For example, highly talented, but isolated individuals could imply a lack of sectoral or governmental support or investment or a lack of connectivity to the global S&T enterprise.

4

Imperatives for Global S&T Engagement and Implications for DoD

"*Second only to a weapon of mass destruction detonating in an American city, we can think of nothing more dangerous than a failure to manage properly science, technology, and education for the common good over the next quarter century*."[1]

The U.S. Commission on National Security/21st Century, chartered by Secretary of Defense William Cohen in 1998, is one of many bodies to document the vital connection between the health of the U.S. science and technology base and national security. We are now more than halfway through the quarter century referenced by the commission in their Phase III report, and the challenge levied in the quote above is intensifying in both importance and difficulty.

The intersection between the products of the science and technology (S&T) enterprise and the instruments of national power is large—and, arguably, expanding. From a historical perspective, our military superiority as well as our economic power are derived in large measure from the technological leadership provided by our nation's S&T enterprise. Retooling these and other instruments for 21st century realities will further strengthen that dependency. But the requisite retooling should be accomplished in an environment in which leadership across a dynamic, interconnected, and expanding global S&T enterprise is no longer dominated by the United States.

Findings and Recommendations

Finding I

Sustained mission success will require the DoD to selectively maintain technological superiority while effectively leveraging advances occurring throughout the global S&T landscape.

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[1] *Road Map for National Security: Imperative for Change*. U.S. Commission on National Security/21st Century (Hart-Rudman Commission, Phase III). 2001. February 15, 2001, p. 30.

Recommendation I

The ASD/R&E should develop a specific, clearly defined and implementable strategy to maintain global awareness of relevant scientific and technological advances that emerge from the dynamic, interconnected, and expanding global S&T enterprise.

Important first steps include:

- **The ASD/R&E, in concert with the R&E Executive Committee (ExCom) and the S&T ExCom, should adopt as an operating principle the use of global technology awareness to inform S&T-related investments across the Defense Research Enterprise (DRE).**
- **The ASD/R&E should, within the Reliance 21 framework, require each Community of Interest to identify and assess (with periodic updates) relevant global research results; those assessments should inform portfolio reviews as well as programmatic investments.**
- **The head of the research enterprise for each of the Services should ensure that Service-specific S&T investment strategies are similarly informed by awareness of related international research.**
- **The heads of the research enterprises for the Services should work collaboratively to develop a regional S&T engagement strategy, together with clearly defined outcomes and measures, to focus the activities of overseas field offices.**

Ultimately, the over-arching strategy should identify key stakeholders in the defense research enterprise (DRE) and beyond, who would benefit from such global awareness—spanning the spectrum from individual researchers to portfolio managers to acquisition program managers and to policy-level decision makers. It should establish clear priorities—perhaps a two-tiered approach distinguishing basic science from technological advances—with sufficient specificity to focus efforts across the DoD. It should establish principles and mechanisms that motivate dynamic capture and sharing of information and insights across the stakeholder communities to enhance decision making while reducing the collective consumption of scarce resources. It should focus on *what* must be accomplished through the definition of measurable outcomes that provide focus and define accountability for department-wide implementation. Importantly, the strategy should articulate an approach that explicitly accounts for the dynamic, interconnected, and expanding nature of the global S&T enterprise. The approach should rely on both human information networks and advanced infor-

mation technology methodologies, some of which may need to be developed for DoD purposes.

As noted in the 2010 Quadrennial Defense Review (QDR) Report, the DoD is not alone in confronting the challenge of maintaining global awareness of important scientific and technological advances. Thus, the strategy might also address how DoD could engage other federal agencies, academia, the private sector, and international partners in building shared awareness of global scientific and technological advances—a *common good* approach.

Finding II

Enterprise-wide S&T situational awareness begins with ensuring its S&E workforce maintains global awareness of S&T and be appropriately engaged with the international research community.

Recommendation II

As "champions" for the S&T workforce,[2] the S&T Executive Committee should establish a workforce development strategy to build and maintain global awareness.

Important first steps include:

- **The ASD/R&E, in concert with the S&T ExCom, should drive a culture across the Defense Research Enterprise that values external ideas and capabilities by consistently communicating and reinforcing the importance of global awareness and engagement.**
- **The ASD/R&E, in concert with the S&T ExCom, should require each COI to share its assessment of relevant global research results with the entire Defense Research Enterprise, and to provide DRE researchers an opportunity to contribute to ongoing assessment efforts.**

An effective workforce development strategy would establish clear expectations for S&T personnel throughout the enterprise together with measures to assess "global readiness." It would include ongoing training opportunities in language and cultural awareness in addition to key technical areas. It would make clear that rotational assignments to overseas field offices are career-building opportunities. And it would establish the priorities and support to enable scientists and engineers at all levels of the DRE to succeed.

The committee acknowledges that security concerns will limit the ability of some DoD scientists and engineers to collaborate globally. Such individuals

[2] Reliance 21. Operating Principles: Bringing Together the DoD Science and Technology Enterprise. January 2014. P. 4.

should nonetheless be expected to maintain awareness of relevant scientific and technological advances that could impact their own work. As noted in Table 1-1, there is a broad spectrum of activities ranging from passive to active that constitute global engagement.

Finding III

DoD and its Services have in place many mechanisms intended to improve awareness of global advances in science and technology, but existing mechanisms are not well integrated; barriers and impediments to successful implementation exist; and outcomes are not systematically measured to assess effectiveness.

Recommendation III

DoD and its Services should conduct a systematic review and analysis of existing mechanisms intended to improve global S&T awareness to identify steps to remove barriers and improve their effectiveness.

Important first steps include:

- **The ASD/R&E, in concert with the R&E ExCom, should establish policy and provide support to enable DRE researchers to attend relevant technical conferences and workshops.**
- **The heads of the research enterprises for the Services should work cooperatively to staff field offices with the scientific, linguistic, and cultural expertise needed to effectively implement their collective regional S&T engagement strategy.**
- **In each of the major overseas field offices, the Service leads should work collaboratively to develop and implement a local inter-agency engagement strategy in order to leverage the presence of other US government agencies.**
- **The ASD/R&E should work with the heads of the research enterprises for the Services to establish DRE-channel reporting in parallel to existing Service-specific reporting from the overseas field offices.**

During the course of this study, the committee identified a number of issues that limit the effectiveness of current efforts to improve awareness of global S&T advances. At the top of the list for both overseas components and Service laboratories are the current policy and resource constraints that limit travel, specifically targeting conference and workshop attendance. The authors of "Globalization of S&T: Key Challenges Facing DOD" note that "[t]he required awareness can be maintained only if the U.S. S&T workforce is a participant in the

global S&T community. This is true for the DOD S&T workforce as well."[3] At present, it is exceptionally difficult for the DoD S&T workforce to be a participant in the global S&T community; the barriers that currently exist have to be lowered.

During meetings and facility visits the study committee consistently asked DoD briefers to describe the benefits of their global engagement activities. While some examples were provided the organizations were unable to clearly articulate what constituted "success" for their missions. The absence of clear objectives impedes the organizations' abilities—both individually and collectively—to effectively prioritize allocation of scarce resources. There is both intellectual and financial value in leveraging international collaborations. At a time of increasing pressure on DoD budgets international collaborations allow DoD to get significantly more reseach impact for the same research dollar. The Services should, in alignment with the Assistant Secretary of Defense for Research and Engineering strategy described in Recommendation 1, establish clear expectations and measurable objectives for their respective global engagement efforts.

The committee also identified concerns relating to staffing, particularly with small overseas contingents tasked to cover a diverse range of scientific domains often across an equally diverse geographic region encompassing several distinct languages and cultures. While some differences exist among the objectives of the service components, it nonetheless appears that a more coordinated approach to staffing would be beneficial—planning collectively to better address the range of scientific and cultural requirements in a given region.

Again, with regard to the overseas components, some sharing of information occurs by virtue of co-location and local collaboration, but the committee observed that the information trail back to the respective service headquarters and laboratories remained stovepiped. Further, it was unclear how (and by whom) information transmitted from the field was used to inform decision making. The Services should collectively establish clear expectations for information sharing and a common channel for information flow as well as a feedback loop to help assess the value of information generated by the overseas components and to provide those components with guidance on information needs. Reliance 21 describes the Research and Engineering Gateway, "a collaborative environment where DoD and industry partners can access information and data,"[4] but it is not clear whether this resource will include the features necessary to enable S&T personnel to access and leverage DRE-wide information to help build global S&T awareness.

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[3] "Globalization of S&T: Key Challenges Facing DOD." Timothy Coffey and Steven Ramberg. Center for Technology and National Security Policy: National Defense University. February 2012, p. 1.

[4] Reliance 21. Operating Principles: Bringing Together the DoD Science and Technology Enterprise. January 2014. Annex: Enabling Knowledge Management Infrastructure.

Decision timeliness is another key success factor given the dynamic global S&T environment. Based on committee visits to Service laboratories and overseas offices it appears that administrative overhead could be reduced and timeliness could be improved through greater use of standard agreements. Further, it was not clear to committee members that information regarding in-place agreements was sufficiently transparent such that those agreements could be leveraged by others.

The committee's observations are based on a very limited sampling; a far more systematic review and analysis is needed to ensure the effectiveness and efficiency of existing mechanisms for global engagement.

Finding IV

The committee did not identify a single "best" approach to maintaining global S&T awareness, but rather believes an integrated suite of methodologies is needed. Opportunities exist for DoD to adopt or adapt practices in use by other institutions and sectors as it implements its strategy to maintain awareness of global advances in science and technology.

Recommendation IV

The DoD and its Services should develop an enterprise-wide solution to implement the strategy called for in Recommendation I.

Important first steps include:

- **The ASD/R&E should establish DRE-wide reporting protocols and a DRE-wide searchable repository to begin building global situational awareness. (The committee notes that the R&E Gateway hosted by DTIC may be useful in this regard.) Topics to be considered include:**
  - **What are the S&T priorities for international reporting?**
  - **Is reporting focused on engagement, collaboration, and/or technology assessments?**
  - **How often and in what format should reporting occur?**
  - **Who should be able to access field S&T assessments?**
  - **What are metrics for successful reporting?**
- **The ASD/R&E should establish a DRE-wide platform to support bibliometrics and other related analytics; a critical enabler is enterprise-wide access to appropriate bibliographic data sets.**

Current DoD approaches to exploiting global S&T advances include the following:

- Reliance on individual researchers (both extra- and intra-mural) to know where the best work in their field is being performed (and by whom), and to craft their proposals accordingly.
- Expecting review panels to have sufficient global awareness to select the best individual and collaborative research proposals for funding.
- Use of scientist visits and exchanges to gain additional insights regarding research performed elsewhere.
- Leveraging overseas presence as platforms for talent-spotting and relationship building in targeted regions of the world.
- Establishing bilateral and multilateral cooperation agreements for joint research programs.

The people-intensive approaches described above sometimes (but not consistently) use bibliometric data mining and other analytic techniques to focus their efforts. Based on inputs received by the committee, it appears that attendance at technical conferences and workshops are more commonly used to identify potentially important work and to spot emerging talent.

A variety of analytically based approaches are in use across DoD by organizations seeking to characterize the evolving global S&T landscape. Such approaches include bibliometric mapping to identify research hot-spots, analysis of patent filings within specific fields to discern institutional strengths, and exploratory application of emerging tools that may enable more efficient machine-based analysis of extremely large data sets. The committee concluded, however, that existing efforts—whether people centric or machine centric—are not integrated to deliver value commensurate with the cumulative investments. The envisioned enterprise solution would leverage the Service-specific mechanisms, as well as provide the connective tissue to afford transparency and efficient sharing of information across all stakeholder communities.

The DoD, however, needs to go beyond knitting together existing mechanisms. The people-centric approaches, while vital to overall success, do not affordably scale to address the scope of the dynamic and expanding global S&T landscape. At the same time, the explosion in available data and information that, if efficiently analyzed, could help researchers, managers, and decision makers spot areas and activities of potential interest, currently overwhelms generally available tools. The committee did not examine the potential of analytics for identifying new disruptive or useful ideas or researchers (i.e., detecting a small, new signal among the noisy S&T landscape). However, the DoD is not alone in facing this challenge; opportunities exist to more effectively leverage the prior work by the National Research Council[5] as well as ongoing work by

[5] See, for example, Persistent Forecasting of Disruptive Technologies: Volumes I and II.

Nesta[6] and others, including researchers who are developing the science and tools for data mining analysis.

During a recent briefing on the 2015 Defense budget, Secretary of Defense, Chuck Hagel, noted that, "…the development and proliferation of more advanced military technologies by other nations…means that we are entering an era where American dominance on the seas, in the skies, and in space can no longer be taken for granted". [7] Acting Assistant Secretary of Defense for Research and Engineering, Alan Shaffer, rearticulated these concerns that "…the capability challenges to [DoD's] R&E program are also increasing…[and are] attributable to changes in the global S&T landscape and the acceleration globally of development of advanced military capabilities that could impact the superiority of US systems".[8] As described early in this report, defense collaboration and engagement with the global research community provide opportunities not only to improve technological situational awareness, but also to maintain productive international partnerships critical for solving important national, regional, and global challenges. This is particularly important for the development of science and technology that, while important to the U.S. defense research enterprise, will be driven by technological advances made by other S&T organizations around the world.

The findings and recommendations described in this report provide an important first step for the DoD to reexamine its current portfolio of international S&T activities and programs and to better leverage global research collaboration, engagement, and awareness efforts occurring across the full defense research enterprise. If the DoD does not develop an enterprise-wide strategy to improve its global S&T awareness and coordination efforts, it runs the risk of losing technological competency with severe implications for economic and national security.

[6] See, for example, Nesta Working Papers on Quantitative Analysis of Technology Futures.
[7] http://www.defense.gov/Transcripts/Transcript.aspx?TranscriptID=5377. Retrieved on April 22, 2014.
[8] http://www.armed-services.senate.gov/imo/media/doc/Shaffer_04-08-14.pdf. Retrieved on April 22, 2014.

Appendixes

A

Committee Member Biographies

ARDEN BEMENT (Co-Chair)

Dr. Arden L. Bement Jr. is the director of the Global Policy Research Institute at Purdue University. Prior to his current position, he was the director of the National Science Foundation (NSF) from 2004 to 2010 and the director of the National Institute of Standards and Technology from 2001 to 2004. He served as a member of the U.S. National Commission for UNESCO and as the vice-chair of the Commission's Natural Sciences and Engineering Committee. He is a member of the U.S. National Academy of Engineering, a fellow of the American Academy of Arts and Sciences, and a fellow of the American Association for the Advancement of Science. Prior to his appointment at NIST, Dr. Bement was the David A. Ross Distinguished Professor of Nuclear Engineering and head of the School of Nuclear Engineering. He has held appointments at Purdue University in the schools of Nuclear Engineering, Materials Engineering, and Electrical and Computer Engineering, as well as a courtesy appointment in the Krannert School of Management. Dr. Bement joined the Purdue faculty in 1992 after a 39-year career in industry, government and academia. His positions included vice president of technical resources and of science and technology for TRW Inc. (1980–1992); Deputy Under Secretary of Defense for Research and Engineering (1979–1980); director, Office of Materials Science, DARPA (1976–1979); professor of nuclear materials, MIT (1970–1976); manager, Fuels and Materials Department and the Metallurgy Research Department, Battelle Northwest Laboratories (1965–1970); and senior research associate, General Electric Co. (1954–1965). He has also been a director of Keithley Instruments Inc. and the Lord Corp. and a member of the Science and Technology Advisory Committee for the Howmet Corp., a division of ALCOA. Dr. Bement holds an engineer of metallurgy degree from the Colorado School of Mines, a M.S. in metallurgical engineering from the University of Idaho, a Ph.D. in metallurgical engineering from the University of Michigan, and honorary doctorates from Cleveland State University, Case Western Reserve University, and the Colorado School of Mines, as well as a Chinese Academy of Sciences Graduate School honorary professorship. He is a retired Lieutenant Colonel of the U.S. Army Corps of Engineers, and a recipient of the Distinguished Service Medal of the

Department of Defense. He has been awarded the Order of the Rising Sun, Gold and Silver Star, from the Empire of Japan and the Chevalier dans l'Ordre National de la Légion d'Honneur from the French Republic.

RUTH DAVID (Co-Chair)

Dr. Ruth David is the president and chief executive officer of Analytic Services Inc. (ANSER), an independent, not-for-profit, public service research institution that provides research and analytic support on national and transnational issues. Since 2009, Dr. David has served as the chair of the Board on Global Science and Technology of the National Research Council; she previously chaired the NRC Standing Committee on Technology Insight—Gauge, Evaluate, and Review, which focused on global technology forecasting. From September 1995 to September 1998, Dr. David was deputy director for Science and Technology at the Central Intelligence Agency. As technical advisor to the director of Central Intelligence, she was responsible for research, development, and deployment of technologies in support of all phases of the intelligence process. She represented the CIA on numerous national committees and advisory bodies, including the National Science and Technology Council and the Committee on National Security. Upon her departure from this position, she was awarded the CIA's Distinguished Intelligence Medal, the CIA Director's Award, the Director of NSA Distinguished Service Medal, the National Reconnaissance Officer's Award for Distinguished Service, and the Defense Intelligence Director's Award. Previously, Dr. David served in several leadership positions at the Sandia National Laboratories, where she began her professional career in 1975. Dr. David has also been an adjunct professor at the University of New Mexico. She has technical experience in digital and microprocessor-based system design, digital signal analysis, adaptive signal analysis, and system integration. Dr. David is a member of the Department of Homeland Security Advisory Council, the National Academy of Engineering, the Corporation for the Charles Stark Draper Laboratory, Inc., and is a senior fellow of the Defense Science Board, and a director of the Hertz Foundation. She also serves on advisory boards for the Stevens Institute of Technology School of Systems and Enterprises, the DoD-sponsored Systems Engineering Research Center, the Wichita State University Dean's Industrial Advisory Board for the College of Engineering, and the Wichita State University Foundation, as well as other governmental organizations. Dr. David received a B.S. in electrical engineering from Wichita State University and a M.S. and Ph.D. in electrical engineering from Stanford University.

JIM C. I. CHANG

Dr. Jim C.I. Chang is currently the visiting chair professor at the National Cheng Kung University in Tainan, Taiwan. He is also an adjunct Professor in the Department of Electrical and Computer Engineering at North Carolina State University (following seven years, 2005–2012, as a research professor there). Prior to that, Dr. Chang served as chief scientist at the Army Research Laboratory

(2010–2012) and as director of materials, mechanics, and micro-systems at the Asian Office of Aerospace Research and Development (AOARD) in Tokyo, Japan (2005–2010). Between 1998 and 2005, Dr. Chang held dual positions as the Army Research Laboratory (ARL) deputy director for basic science and the director of the Army Research Office (ARO). As the ARL deputy director for basic science, Dr. Chang was the senior science and technology executive charged with oversight of the entire ARL basic research (6.1) program. As such he was responsible for maintaining a coherent basic research program among all of the Army 6.1 components and assuring the transition of research to technology development. As the ARO Director, Dr. Chang managed an extramural research program in the physical and engineering sciences that included over $160 million in single investigator research and over 40 multidisciplinary research centers. Between 1990 and 1998, Dr. Chang was the director of the Aerospace and Materials Sciences Directorate for the Air Force Office of Scientific Research (AFOSR), where he managed the $50 million Air Force basic research programs supporting aircraft, tactical and ballistic missiles, and spacecraft design and operation. Between 1998 and 1990, Dr. Chang was chief scientist at the Naval Air Systems Command; prior to that he served as manager in the Office of Systems Assessment with the National Aeronautics and Space Administration (1988–1989). Between 1978 and 1988, Dr. Chang was a branch head at the Naval Research Laboratory where he led research and development efforts in materials, mechanics, structures, and thermal sciences. Dr. Chang was born in China during World War II. After completing his B.S. in hydraulic engineering from Taiwan Cheng-Kung University, he immigrated to the United States and received a M.S. in civil engineering at Michigan Technological University and a Ph.D. in theoretical and applied mechanics at Cornell University. Dr. Chang entered federal service in 1978. He has published more than 40 publications and served as an associate editor and reviewer for several professional journals.

PAUL CHU

Dr. Paul Chu is professor of physics and T.L.L. Temple Chair of Science in the College of Natural Sciences and Mathematics at the University of Houston specializing in superconductivity, magnetism, and dielectrics. Dr. Chu also previously served as president of the Hong Kong University of Science and Technology from 2001 to 2009. Born in Hunan, China, Dr. Chu holds a B.S. in physics from National Cheng Kung University in Taiwan (1962), a M.S. in physics from Fordham University (1965), and a Ph.D. in physics from the University of California at San Diego (1968). After two years doing industrial research with Bell Laboratories at Murray Hill, New Jersey, Dr. Chu joined the faculty at Cleveland State University first as assistant professor of physics in 1970 and then as associate professor and professor of physics in 1973 and 1975, respectively. In 1979, Dr. Chu became professor of physics at the University of Houston. In 1987, after discovering (with Maw-Kuen Wu) superconductivity above 77K in YBCO, Dr. Chu became director of the Texas Center for Superconductivity (un-

til 2001) and T.L.L. Temple Chair of Science, which he still holds today. Dr. Chu has previously served as a consultant and visiting staff member at Bell Laboratories, Los Alamos Scientific Laboratory, the Marshall Space Flight Center, Argonne National Laboratory, and DuPont. He has received numerous awards and honors for his work in superconductivity, including the National Medal of Science, the Comstock Prize in Physics, and the International Prize for New Materials in 1988. He was an invited contributor to the White House National Millennium Time Capsule at the National Archives in 2000 and was selected the Best Researcher in the U.S. by U.S. News and World Report in 1990. In 1989, Dr. Chu was elected a fellow of the American Academy of Arts and Sciences. He is a member of the National Academy of Sciences, Chinese Academy of Sciences (foreign member), Academia Sinica, Russian Academy of Engineering, and the Third World Academy of Sciences.

SUSAN COZZENS

Dr. Susan E. Cozzens is professor of public policy, director of the Technology Policy and Assessment Center, and vice provost for graduate education and faculty affairs at Georgia Tech. Dr. Cozzens's research interests are in science, technology, and innovation policies in developing countries, including issues of equity, equality, and development. She is active internationally in developing methods for research assessment and science and technology indicators. Her current projects are on water and energy technologies, nanotechnology, social entrepreneurship, pro-poor technology programs, and international research collaboration. From 1998 through 2003, Dr. Cozzens served as chair of the Georgia Tech School of Public Policy. From 1995 through 1997, Dr. Cozzens was director of the Office of Policy Support at the National Science Foundation. The Office of Policy Support coordinated policy and management initiatives for the NSF director, primarily in peer review, strategic planning, and assessment. Before joining Georgia Tech, Dr. Cozzens spent 11 years on the faculty of Rensselaer Polytechnic Institute. Dr. Cozzens holds a Ph.D. in sociology from Columbia University (1985) and a bachelor's degree from Michigan State University (1972).

PATRICIA L. GRUBER (01/09/13–12/31/13)

Dr. Patricia L. Gruber is currently technical director at the Office of Naval Research Global. Prior to that, Dr. Gruber was vice President of the Maritime Systems Division at the Batelle Memorial Institute. Prior to this position, Dr. Gruber was the deputy director of the Applied Research Lab (ARL) at the Pennsylvania State University (2009–2012). Dr. Gruber has also served as the director of research at the Office of Naval Research, where she was responsible for Naval S&T strategic planning and for the overall integration of the Discovery and Invention portfolio (6.1 and early 6.2) in support of naval mission areas (2006–2008). Prior to her ONR assignment, Dr. Gruber served as a senior research associate at ARL Penn State (2003–2005). Dr. Gruber has held a number

of technical management and business development positions at Lucent Technologies Bell Laboratories and Marconi Communications (1996–2002). At AT&T Solutions, she was a solution architect responsible for development and implementation of complex IT outsourcing contracts. As a Distinguished Member of Technical Staff at AT&T Bell Laboratories, she was a program manager for Navy undersea surveillance programs. Dr. Gruber began her career as a research physicist in the Acoustics Division at the Naval Research Laboratory. Dr. Gruber is a recipient of the Superior Public Service Award. She is a consultant to the Army Science Board and is a member of the Acoustical Society of America. Dr. Gruber holds a B.S. in meteorology from Pennsylvania State University and a M.S. and Ph.D. in marine physics from the University of Miami.

DANIEL HASTINGS

Dr. Daniel Hastings is the Cecil and Ida Green Education Professor of Aeronautics and Astronautics and Engineering Systems. He has taught courses and seminars in plasma physics, rocket propulsion, advanced space power and propulsion systems, aerospace policy, technology and policy, and space systems engineering. From 1997 to 1999, Dr. Hastings was the U.S. Air Force's chief scientist. In that role, he was chief scientific adviser to the chief of staff and the secretary and provided assessments on a wide range of scientific and technical issues affecting the Air Force mission. He led influential studies about Air Force investment in space, global energy projection, and options for a 21st century science and technology workforce. Dr. Hastings' recent research has concentrated on space systems and space policy, and on spacecraft-environmental interactions, space propulsion, space systems engineering, and space policy. He has published many papers and a book on spacecraft-environment interactions, and several papers in space propulsion and space systems. He has led national studies on government investment in space technology. Dr. Hastings joined the MIT faculty as an assistant professor in 1985. He served as the director of the MIT Technology and Policy Program, the Engineering Systems Division and as the dean for undergraduate education. In his role as dean at MIT, he focused on substantially increasing the number and quality of the global experiences in the MIT undergraduate education. He is currently the director and CEO of the Singapore MIT Alliance for Research and Technology, one of the global S&T enterprises for MIT.

PETER HOFFMAN

Mr. Peter Hoffman is vice president of intellectual property management at the Boeing Company. Prior to this position, he served as director of global research and development strategy for Boeing Research & Technology, the company's advanced research organization. In that role, he was responsible for developing technology collaboration relationships with companies, universities, and national laboratories around the world. During the past decade, Mr. Hoffman has played a leadership role in the expansion of Boeing's global technology activi-

ties and was instrumental in the establishment of research centers in Australia, India, and China and numerous technology relationships in Europe, Asia, the Middle East, and the Americas. Mr. Hoffman joined Boeing in 1984. He has held positions in international business development and spent 14 years conducting research in the area of advanced materials and structures. Mr. Hoffman earned a bachelor's of science degree in mechanical engineering technology, a master's of science degree in mechanical engineering from the University of Tennessee, a master's of manufacturing engineering from Washington University in St. Louis, and a master's of international business from St. Louis University.

ANTHONY (BUD) ROCK

Mr. Anthony Rock has been the chief executive officer for the Association of Science and Technology Centers since 2009. Previous to this position, he served as vice president for global engagement at Arizona State University (ASU), where he was responsible for expanding global awareness among students and developing new and creative international programs of research and scholarship. Before joining ASU, Mr. Rock had a distinguished three-decade career in U.S. government service, much of it within the Department of State, promoting scientific and technological collaboration throughout the world. His diplomatic service culminated in his five-year appointment as principal deputy assistant secretary of state responsible for oceans, environment, and science. Mr. Rock served abroad as minister for science, technology, environment, health, and nonproliferation affairs in the United States Embassy in Paris, France; was the counselor for environment, science, technology, and health at the United States Mission to the European Union in Brussels, Belgium; and was counselor for environment, science, technology, and health at the United States Embassy in Tel Aviv, Israel. Mr. Rock also held positions in the Office of the United States Trade Representative, Executive Office of the President, as director for European technology and trade affairs and as director of Middle East trade affairs. In the Department of State, Mr. Rock served as chief of policy planning in the Bureau of Oceans and International Environmental and Scientific Affairs (OES); chief for international health policy and chief of international technology policy. Prior to his diplomatic service, Mr. Rock was employed by the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

JAMES WILSDON

Dr. James Wilsdon is professor of science and democracy in SPRU (Science Policy Research Unit) at Sussex University in the United Kingdom. Dr. Wilsdon joined SPRU in December 2011. From 2008 to 2011, he was the founding director of the Science Policy Centre at the Royal Society, the UK's national academy of science, where he oversaw policy studies on topics such as geoengineering, food security, science diplomacy, open science, and the future

of international scientific collaboration. He also led the Royal Society's evidence gathering and advocacy for investment in research through the 2010 UK General Election and Spending Review. From 2001 to 2008, Dr. Wilsdon worked at the London-based think tank Demos, first as head of strategy, and then as head of science and innovation. At Demos, he was also project director of "The Atlas of Ideas," a two-year study of science in emerging economies, described by the *Financial Times* as "the most comprehensive analysis yet of science and innovation in China, India and South Korea." From 1997 to 2001, he was senior policy adviser at the sustainability charity Forum for the Future. Dr. Wilsdon has researched and written widely on science and innovation policy, emerging technologies, and the globalization of research. His publications include *The Scientific Century* (Royal Society, 2010), *The Atlas of Ideas* (Demos, 2007), *China: the next science superpower?* (Demos, 2007), *The Public Value of Science* (Demos, 2005), *See-through Science* (Demos, 2004), and Digital Futures (Earthscan, 2001). He reviews regularly for the *Financial Times* and *Times Higher Education*, and has also written for *Nature,* the *Guardian, China Daily, and openDemocracy*. Dr. Wilsdon has a first-class degree in philosophy and theology from Oxford University and a doctorate in technology policy from Middlesex University. He is a fellow at NESTA, the UK foundation for innovation; and an associate fellow at Cambridge University's Centre for Science and Policy. In September 2012, he was appointed to the Governing Board of CISTRAT (International Research and Training Centre for Science and Technology Strategy) in Beijing, a new center established under the joint auspices of UNESCO and China's Ministry of Science and Technology.

CELIA MERZBACHER

Dr. Celia Merzbacher is the vice president of innovative partnerships at the Semiconductor Research Corporation. In this role, she is primarily responsible for developing novel partnerships with stakeholders in government and the private sector in support of SRC's research and education goals. Prior to joining SRC, Dr. Merzbacher was assistant director for technology R&D in the White House Office of Science and Technology Policy (OSTP), where she coordinated and advised on a range of issues, including nanotechnology, technology transfer, technical standards, and intellectual property. At OSTP she oversaw the National Nanotechnology Initiative, the multiagency federal program for nanotechnology research and development. She also served as executive director of the President's Council of Advisors on Science and Technology, which is composed of leaders from academia, industry and other research organizations, and advises the president on technology, scientific research priorities, and math and science education. Previously, Dr. Merzbacher was on the staff of the Naval Research Laboratory (NRL) in Washington D.C. As a research scientist at NRL, she developed advanced optical materials, for which she received a number of patents. She also worked in the NRL Technology Transfer Office where she was responsible for managing NRL intellectual property. Dr. Merzbacher served on the

Board of Directors of the American National Standards Institute and led the U.S. delegation to the Organization for Economic Cooperation and Development Working Party on Nanotechnology. Dr. Merzbacher received her B.S. in geology from Brown University and M.S. and Ph.D. in geochemistry and mineralogy from the Pennsylvania State University.

B

Contributors to the Study

Although the briefers listed below provided much useful information of various kinds to the committee, they were not asked to endorse the content of this study, nor did they see the final draft of this report before its release.

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Washington, DC: July 24–25, 2013

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Washington, DC: October 29–309, 2013

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C

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Paul Harris, The Australian National University
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Jason Frohnmayer, Embassy of the United States in Australia
Matt Murray, Embassy of the United States in Australia
Christopher Westhoff, Embassy of the United States in Australia
Les Rymer, The Group of Eight Ltd.
Ian Chubb, Office of the Chief Scientist of Australia
Jane Urquhart, Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, Australia
Tony Peacock, Cooperative Research Centres Association, Australia
John Bell, Australian Academy of Technological Sciences and Engineering
Denis Blight, Australian Academy of Technological Sciences and Engineering
Joanne Daly, Australian Academy of Technological Sciences and Engineering
Aidan Byrne, Australian Research Council
Fiona Cameron, Australian Research Council
Mary T. Kelly, Australian Research Council
Mirian Simms, Australian Research Council
Justin Withers, Australian Research Council
Brian Yates, Australian Research Council
Mark S. Smith, Commonwealth Scientific & Industrial Research Organisation, Australia
Juliet Bell, Commonwealth Scientific & Industrial Research Organisation, Australia
Ian Poll, Defence Scientific Advisory Council, U.K. Ministry of Defence
Bryan Wells, Defence Science and Technology, U.K. Ministry of Defence
Edward Heartney, Embassy of the United States in London
Anna Lovelock, Embassy of the United States in London
Clayton Stewart, Office of Naval Research Global London
Shawn Thorne, Office of Naval Research Global London
CDR Kyle Gresham, U.S. Air Force European Office of Aerospace Research and Development
Randall Pollak, U.S. Air Force European Office of Aerospace Research and Development
Gregg Abate, European Office of Aerospace Research and Development
Michael Schwartz, U.S. Army International Technology Center-Atlantic
Barrett Flake, Defense Threat Reduction Office-London
COL Keith Hirschman, TBC
Sophie Laurie, Research Councils U.K.
Jane Nicholson, Engineering and Physical Sciences Research Council
Chris Bradley, Foreign and Commonwealth Office, UK
Andrew Jackson, Foreign and Commonwealth Office, UK
David Wilson, Department for Business, Innovation & Skills, UK

Susan Vesel, U.S. Mission to the European Union, Brussels
Ángeles Rodríguez Peña, European Cooperation in Science and Technology
David Wilkinson, Joint Research Centre, European Commission
Jocelyne Gaudin, Joint Research Centre, European Commission
Vena Mitkova Nievergelt, Joint Research Centre, European Commission
Agnija Rasa, Joint Research Centre, European Commission
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Katarina Wilhelmsen, Swedish Defence Research Agency
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Anna Ledin, Swedish Agency for Growth Policy Analysis
Enrico Deiaco, Head, Swedish Agency for Growth Policy Analysis
Martin Wikström, Swedish Agency for Growth Policy Analysis
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Annette Moth Wiklund, Swedish Research Council
Mats Ulfendah, Swedish Research Council
Staffan Normark, Royal Swedish Academy of Sciences
Britt-Marie Sjöberg, Royal Swedish Academy of Sciences
Heléne Sundström, Royal Swedish Academy of Sciences
Mattias Jennerholm, Ministry of Education and Research

C.2 Contact Information for Organizations Visited Overseas

Japan Science and Technology Agency (JST)
Science Plaza, 5-3, Yonbancho, Chiyoda-ku, Tokyo 102-8666 Japan
http://www.jst.go.jp/EN/

Japan Society for the Promotion of Science (JSPS)
Kojimachi Business Center Building, 5-3-1 Kojimachi, Chiyoda-ku, Tokyo 102-0083
http://www.jsps.go.jp/english/

IBM Research–Tokyo
NBF Toyosu Canal Front Building, 5-6-52 Toyosu, Koto-ku,
Tokyo, 135-8511 Japan
http://www.research.ibm.com/labs/tokyo/

IHI Corporation
Toyosu IHI Building. 1-1, Toyosu 3-chome, Koto-ku, Tokyo 135-8710, Japan
https://www.ihi.co.jp/en/index.html

Chungshan Institute of Science and Technology (CIST), Taiwan
No.481, Sec. chia an, Zhongzheng Road, Longtan Shiang, Taoyuan County 325,
Taiwan (R.O.C.)
http://cs.mnd.gov.tw/english/

Industrial Technology Research Institute (ITRI), Taiwan
195, Sec.4, Chung Hsing Road, Chutung, Hsinchu, 31040, Taiwan (R.O.C.)
https://www.itri.org.tw/eng/

Ministry of Economic Affairs (MOEA), Taiwan
15 Fuzhou St., Taipei, 10015, Taiwan (R.O.C.)
http://www.moea.gov.tw/Mns/english/home/English.aspx

National Taiwan University (NTU)
No. 1, Sec. 4, Roosevelt Road, Taipei, 10617, Taiwan (R.O.C.)
http://www.ntu.edu.tw/engv4/

Academia Sinica (AS), Taiwan
128 Academia Road, Section 2, Nankang, Taipei 115, Taiwan (R.O.C.)
https://www.sinica.edu.tw/main_e.shtml

National Applied Research Laboratories (NARL), Taiwan
3F, No. 106, Sec. 2, Heping E. Rd., Taipei City 106, Taiwan (R.O.C.)
http://www.narlabs.org.tw/en/

Ministry of Science and Technology (formerly National Science Council), Taiwan
106, Sec. 2, Heping E. Road, Taipei, 10622, Taiwan, (R.O.C.)
http://web1.most.gov.tw/

Executive Yuan, Taiwan
No.1, Sec. 1, Zhongxiao E. Road, Zhongzheng District, Taipei City 10058,
Taiwan (R.O.C.)
http://www.ey.gov.tw/en/

Ministry of Science and Technology (MOST), Thailand
75/47, Phrachomklao Building, RAMA 6 Road, Thung-Phyathai,
Ratchathewee, Bangkok 10400, Thailand
http://www.most.go.th/eng/

National Science Technology and Innovation Policy Office (STI), Thailand
319 Chamchuri Square BD., 14, Phayathai Road, Patumwan,
Bangkok 10330, Thailand
http://www.sti.or.th/en/index.php

Chulalongkorn University, Thailand
254 Phayathai Road, Pathumwan, Bangkok 10330, Thailand
http://www.chula.ac.th/cuen/

National Research Council of Thailand (NRCT)
196 Phaholyothin Road, Ladyao, Chatuchak, Bangkok 10900, Thailand
http://en.nrct.go.th/en/Home.aspx

Thailand Research Fund (TRF)
14th Floor, SM Tower 979/17-21 Phaholyothin Road,
Samsaen-nai, Phayathai, Bangkok 10400, Thailand
http://www.trf.or.th/

Embassy of the United States, Bangkok, Thailand
95 Wireless Road, Bangkok, 10330, Thailand
http://bangkok.usembassy.gov/index.html

National Science and Technology Development Agency (NSTDA), Thailand
111 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Khlong Luang,
Pathum Thani 12120, Thailand
http://www.nstda.or.th/eng/

The Siam Cement Public Company Limited (SCG), Thailand
1 Siam Cement Road, Bangsue, Bangkok 10800, Thailand
http://www.scg.co.th/en/01corporate_profile/

Joint U.S.-Thai Armed Forces Institute of Medical Sciences (AFRIMS) Thailand
315/6 Rajvithi Road, Bangkok 10400, Thailand
http://www.afrims.org/

Thailand Institute of Scientific and Technological Research (TISTR)
35 Mu 3 Tambon Khlong Ha, Amphoe Khlong Luang, Changwat
Pathum Thani 12120, Thailand
http://www.tistr.or.th/tistr_en/index_en.php?pages=home

Federation of Thai Industries, Thailand
Queen Sirikit National Convention Center, Zone C. 4th Floor,
60 New Rachadapisek Road, Klongtoey, Bangkok 10110, Thailand
http://www.fti.or.th/2011/thai/index.aspx

PTT Global Chemical Public Company Limited
555/1 Energy Complex, Building A, 14th–18th Floor, Vibhavadi Rangsit Road,
Chatuchak, Chatuchak, Bangkok 10900, Thailand
http://www.pttgcgroup.com/

Kasetsart University
50 Ngam Wong Wan Road, Ladyaow Chatuchak, Bangkok 10900, Thailand
http://www.ku.ac.th/english/

Science and Technology Australia
Suite 4, 7 Napier Close, Deakin ACT 2600, Australia
http://scienceandtechnologyaustralia.org.au/

Australian Academy of Science
Ian Potter House, Gordon Street, Acton ACT 2601, Australia
http://www.science.org.au/

Defence Science and Technology Organisation (DSTO), Australia
Department of Defence, Russell Building 1, Russell ACT 2600, Australia
http://www.dsto.defence.gov.au/

The Australian National University
Barry Dr, Acton ACT 0200, Australia
http://about.anu.edu.au/

Embassy of the United States, Canberra, Australia
1 Moonah Pl, Yarralumla ACT 2600, Australia
http://canberra.usembassy.gov/

The Group of Eight Limited, Australia
Level 2, 101 Northbourne Avenue, Turner ACT 2612, Australia
http://www.go8.edu.au/

Office of the Chief Scientist of Australia
Industry House, 10 Binara Street, Canberra City, ACT 2601 Australia
http://www.chiefscientist.gov.au/

Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, Australia (reorganized as the Department of Industry on September 18, 2013)

Industry House, 10 Binara Street, Canberra City, ACT 2600 Australia
http://www.innovation.gov.au/Pages/default.aspx

Cooperative Research Centres Association, Australia
Engineering House, 11 National Circuit, Barton ACT 2600, Australia
http://crca.asn.au/

Australian Academy of Technological Sciences and Engineering
Level 1 / 1 Bowen Crescent, Melbourne Vic 3004, Australia
http://www.atse.org.au/

Australian Research Council
Level 2, 11 Lancaster Place, Majura Park ACT 2609, Australia
http://www.arc.gov.au/

Commonwealth Scientific & Industrial Research Organisation, Australia
Clunies Ross Street, Black Mountain, ACT 2601, Australia
http://www.csiro.au/

Defence Scientific Advisory Council, Ministry of Defence, UK
01.M.14, MOD Main Building, Whitehall, London, SW1A 2HB, UK
https://www.gov.uk/government/organisations/defence-scientific-advisory-council/about

Embassy of the United States, London, England
24 Grosvenor Square, London W1A 2LQ, United Kingdom
http://london.usembassy.gov/about-us.html

Office of Naval Research Global London
2 Providence Court, Mayfair, London W1K 6PR, UK
http://www.onr.navy.mil/en/Science-Technology/ONR-Global.aspx

Air Force European Office of Aerospace Research and Development, London
2 Providence Court, Mayfair, London W1K 6PR, UK
http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=16662/

U.S. Army International Technology Center-Atlantic, London
2 Providence Court, Mayfair, London W1K 6PR, UK
http://www.rdecom.army.mil/itcatlantic/aboutus.html

Research Councils UK
14th Floor, 1 Kemble Street, London WC2B 4AN, UK
http://www.rcuk.ac.uk/

Engineering and Physical Sciences Research Council, UK
Polaris House, North Star Avenue, Swindon SN2 1ET, UK
http://www.epsrc.ac.uk/Pages/default.aspx

Foreign and Commonwealth Office (FCO), UK
King Charles St, London SW1A 2AH, United Kingdom
https://www.gov.uk/government/organisations/foreign-commonwealth-office/about

Department for Business, Innovation & Skills, UK
1 Victoria Street, London SW1H 0ET, UK
https://www.gov.uk/government/organisations/department-for-business-innovation-skills/about

U.S. Mission to the European Union, Brussels
Zinnerstraat - 13 - Rue Zinner, B-1000 Brussels, Belgium
http://useu.usmission.gov/

European Cooperation in Science and Technology, Belgium
Avenue Louise 149, 1050 Brussels, Belgium
http://www.cost.eu/

Joint Research Centre, European Commission, Belgium
Rue du Champ de Mars 21, 1050 Brussels, Belgium
http://ec.europa.eu/dgs/jrc/

Directorate-General for Research & Innovation, European Commission
Square Frere Orban, 8, B-1049 Brussels, Belgium
http://ec.europa.eu/research/index.cfm?pg=dg

Uppsala University, Sweden
S:t Olofsgatan 10B, 751 05 Uppsala, Sweden
http://www.uu.se/

Vinnova, Sweden
Mäster Samuelsgatan 56, 101 58 Stockholm, Sweden
http://www.vinnova.se/en/

Swedish Defence Research Agency
Gullfossgatan 6, Kista, 164 98 Stockholm, Sweden
http://www.foi.se/en/

Swedish Agency for Growth Policy Analysis
Regeringsgatan 67, 101 31 Stockholm, Sweden
http://www.tillvaxtanalys.se/en/home.html

Ericsson, Sweden
Torshamnsgatan 21, Kista, 164 83 Stockholm, Sweden
http://www.ericsson.com/thecompany/company_facts/worldwide/eu/se

Swedish Research Council
Västra Järnvägsgatan 3, Stockholm, Sweden
http://www.vr.se/inenglish.4.12fff4451215cbd83e4800015152.html

Royal Swedish Academy of Sciences
Lilla Frescativägen 4A, SE-114 18 Stockholm, Sweden
http://www.kva.se/en/

Ministry of Education and Research, Sweden
Drottninggatan 16, SE-103 33 Stockholm, Sweden
http://www.government.se/sb/d/2133

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Sample Questions Asked During the Committee's Fact-Finding Visits

Committee visits to Naval Research Laboratory,
Air Force Research Laboratory and Army Research Laboratory
Some questions asked of the laboratories on
Technology Awareness and Global Engagement

- Is global engagement in S&T an explicit objective in any research strategy or planning documents?
- What is your strategy for determining what the 'best' S&T is?
- What mechanisms does lab management employ to facilitate international awareness and engagement among its technical staff?
- How do you interact with your overseas field offices?
- How do you engage with the external research community in each of your fields? Specifically, with whom and how do you engage internationally?
- How do you capture the information you receive, both from conferences and from your direct interaction with foreign researchers? How, and with whom, is this information shared (across research groups, lab-wide, with ASD(R&E) and across DOD S&T enterprise, and beyond)?
- How do you leverage S&T knowledge and investments made by other researchers across USG?
- What are the biggest barriers to:
  1) understanding what important S&T is happening globally?
  2) being engaged in international collaborations?
- What can be done to remove the barriers mentioned above.

Questions/discussion topics for meetings with overseas organizations

Mission:

- Do you have an international S&T mission? What is it?
  - Is it to maintain S&T Awareness?
  - Is it to build S&T collaborations with foreign partners? How do you choose global partners?
  - Is it to fund research in other countries? Is it to influence future research priorities/investments?
  - Is there a short–term versus and long-term mission or strategy?

Technology Awareness:

- What mechanisms do you use to maintain global S&T awareness?
- How do you prioritize which technologies or researchers you would like to engage with?
- What is your strategy for determining what the 'best' science is?
- Do you use data analytics?
- Do you participate in conferences? Which conferences do you attend and why?
- Is your S&T engagement strategy specific to individual countries?

Building and Sustaining Relationships:

- For each of the following organizations in your country, how would you characterize their willingness to engage with you in S&T: universities, industries, and government agencies? With which have you been the most and least successful, and why? Does your engagement approach vary across each sector?
- What about for U.S. universities, U.S. industries, and U.S. government agencies (both those in the U.S. and those with overseas offices)?
- What is your relationship to your national defense science enterprise?
- Do you ever work with the U.S. defense science enterprise?
- How do you build and sustain relationships with foreign researchers or organizations?

Coordination:

- How do you capture the information you receive, both from conferences and from your direct interaction with foreign researchers?
- How, and with whom, is this information shared?
- How do you create opportunities to integrate foreign research into your own organization's larger S&T portfolio?

Metrics:

- How do you measure the value or success of your global S&T engagement efforts in the near-term (1-5 years) and longer-term (5-10 years)?
- What are the biggest barriers to success?
- Do you have examples of work, research, products, etc. that resulted from international research engagement or collaboration?

Career Development:

- What is the career trajectory for staff who are involved in international S&T programs

Questions for the Services' Overseas Offices

Mission:

- What is your mission?
    - Is it S&T Awareness (eyes and ears on the ground?
    - Is it building S&T collaborations with U.S. partners in DoD Labs? in universities?
    - Is it to fund actual research?
    - Is it to influence research priorities/investments, and if so, for whom?
    - Is there a short–term (e.g. taking advantage of a new S&T capability) and long-term (e.g. building an enduring relationship in S&T collaboration) mission?
- How would you differentiate your mission from that of the other Service offices in Tokyo?
- How is your mission complementary or different with respect to supporting DOD leveraging of S&T overseas?

Technology Awareness:

- What mechanisms do you use to maintain global S&T awareness?
- How do you prioritize which technologies or researchers you would like to engage with?
- What is your strategy for determining what the 'best' science is?
- Do you use data analytics?
- Which conferences do you attend and why?
- Do you have a different S&T engagement strategy for each country in your area of responsibility?

Building and Sustaining Relationships:

- For each of the following, how would you characterize their willingness to engage with you in S&T: universities, industry, and government? With which have you been the most and least successful, and why? Does your approach for S&T engagement vary across each of these sectors?
- What funds does your Tokyo office have to support foreign researchers? How do you prioritize which projects you will fund? Which countries receive the majority of funding? How many of these projects go on to receive subsequent funding from your home office?
- How do you sustain relationships with foreign researchers (particularly ones with whom you do not have established bilateral science programs, such as the Taiwan NanoBio program)?
- Do you work primarily with university researchers or government officials (and if so, are they foreign defense science)?

- How do you sell "collaboration or partnership with the U.S." to foreign researchers (what is your elevator pitch)? What does the U.S. gain from these collaborations?

Coordination:

- How do you capture the information you receive, both from conferences and from your direct interaction with foreign researchers?
- How, and with whom, is this information shared?
- How do you coordinate your efforts with the other Service offices in Tokyo?
- How do you leverage S&T knowledge and investments, as well as personal/institutional/governmental relationships, made by the other Service offices in Tokyo?
- Do you interact with other U.S. agencies that have international S&T offices?
- What is your relationship with NATO STO and TTCP?

Connectivity to your U.S. S&T Office:

- How do you stay abreast of the S&T areas of interest to your U.S. counterparts?
- How do you create opportunities to integrate foreign research into your Service's larger S&T portfolio?
- Do you have examples of work that you funded or introduced that was subsequently funded by your U.S. office?

Metrics:

- How do you measure success in the near-term (1-5 years) and longer-term (5-10 years)? E.g., is it how much funding they give out? how well they connect people and technology to the U.S? Are there citable example of people or technology that has benefitted the U.S. DoD?
- What are the biggest barriers to success?
- What steps have you taken to compensate for shrinking travel budgets while maintaining awareness of global S&T?
- Do you believe you have adequate staffing (in terms of number and scientific expertise) and resources (e.g., for infrastructure, programs, conferences, site visits, funding for foreign research, etc.) to accomplish your mission?

Career Development:

- What was your most immediate position?
- What kind of training, if any, did you receive for this position?
- What is the typical career trajectory for staff rotating through the overseas offices?

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Abbreviations

ACE	American Council on Education
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AFRIMS	U.S.-Thai Armed Forces Research Institute for Medical Sciences
AFRL	Air Force Research Laboratory
AMC	Army Materiel Command
AOARD	Asian Office of Aerospace Research & Development
ARO	Army Research Office
ARL	Army Research Laboratory
ASA(AL&T)	Assistant Secretary of the Army for Acquisition, Logistics & Technology
ASAF(AQ)	Assistant Secretary of the Air Force for Acquisition
ASD(R&E)	Assistant Secretary of Defense for Research & Engineering
ASEAN	Association of South East Asian Nations
ASN(RD&A)	Assistant Secretary of the Navy for Research, Development & Acquisition
BGST	Board on Global Science and Technology
BRIC	Brazil, Russia, India, China
CDC	Centers for Disease Control
CERN	European Organization for Nuclear Research
COI	Communities of Interest
DARPA	Defense Advanced Research Projects Agency
DASA(R&T)	Deputy Assistant Secretary of the Army for Research & Technology
DASAF(ST&E)	Deputy Assistant of the Air Force for Science, Technology & Engineering
DDR&E	Director of Defense Research for Research and Engineering
DHS	Department of Homeland Security
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DRE	Defense Research Enterprise

DREN	Defense Research and Engineering Network
DSB	Defense Science Board
DSTO	Defence Science and Technology Organisation (Australia)
DTRA	Defense Threat Reduction Agency
EC	European Commission
EMBL	European Molecular Biology Laboratory
EOARD	European Office of Aerospace Research & Development
EPA	Environmental Protection Agency
ERASMUS	European Community Action Scheme for the Mobility of University Students
EU	European Union
ESTH	Environment, Science, Technology and Health
FAST	Field Assistance in Science & Technology
FDA	Food and Drug Administration
FFRDC	Federally Funded Research & Development Center
GSTOC	Committee on Globalization of Science and Technology: Opportunities and Challenges for the Department of Defense
ICRI	Intel International Collaborative Research Institute
ICUK	Innovation China UK Program
IODP	Integrated Ocean Drilling Program
IPOC	International Point of Contact
ISTCs	Intel Science and Technology Centers
ITC	International Technology Center
ITRI	Industrial Technology Research Institute
JSPS	Japan Society for the Promotion of Sciences
NASA	National Aeronautics and Space Administration
NATO STO	North Atlantic Treaty Organization Science & Technology Organization
NICOP	Naval International Cooperation Opportunities in S&T Program
NIH	National Institutes of Health
NIPO	Navy International Programs Office
NIPR	Non-classified Internet Protocol
NIST	National Institute of Standards & Technology
NOAA	National Oceanographic & Atmospheric Agency
NRC	National Research Council
NRE	Naval Research Enterprise
NRL	Naval Research Laboratory
NSB	National Science Board
NSF	National Science Foundation
OES	Bureau of Oceans and International Environmental & Scientific Affairs
ONR	Office of Naval Research
ONR-G	Office of Naval Research Global
OSD	Office of the Secretary of Defense

OSTP	Office of Science & Technology Policy
PIRE	Partnerships for International Research & Education
QDR	Quadrennial Defense Review Report
RDEC	Research, Development & Engineering Center
RDECOM	Research, Development & Engineering Command
RFEC	RDECOM Forward Element Command
R&D	Research and Development
R&E EXCOM	Research & Engineering Executive Committee
SKA	Square Kiometre Array Project
SOARD	Southern Office of Aerospace Research & Development
STI	Science, Technology, and Innovation
SWOT	Strengths, Weaknesses, Opportunities & Threats
S&Es	Scientists and Engineers
S&T	Science & Technology
TRL	Technology Readiness Level
TTCP	The Technical Cooperation Program
UARC	University-Affiliated Research Center
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USMC	U.S. Marine Corps

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Listing of International Branch Campuses from GlobalHigherEd.org

The table below is adapted from GlobalHigherEd.org (http://www.globalhighered.org/branchcampuses.php, last accessed on March 31, 2014), a site maintained by the Cross-Border Education Research Team (C-BERT) at the State University of New York at Albany. According to C-BERT, an international branch campus is defined as an entity that is owned, at least in part, by a foreign education provider; operated in the name of the foreign education provider; engages in at least some face-to-face teaching; and provides access to an entire academic program that leads to a credential awarded by the foreign education provider.

Institution Name	Host Country	Home Country
Empire State College	Albania	USA
U of Bologna	Argentina	Italy
Lomonosov Moscow State U (in development)	Armenia	Russia
Moscow State U of Economics, Statistics and Informatics	Armenia	Russia
Esmod Jakarta, Int'l U Fashion Group	Indonesia	France
SP Jain Centre of Management	Australia	India
U College London	Australia	UK
CMU	Australia	USA
Webster U	Austria	USA
Lomonosov Moscow State U	Azerbaijan	Russia
Royal College of Surgeons	Bahrain	Ireland
AMA Int'l U	Bahrain	Philippines
NY Inst. of Tech.	Bahrain	USA
Grameen Caledonian College of Nursing	Bangladesh	UK
Boston U	Belgium	USA
Limkokwing U of Creative Tech.	Botswana	Malaysia
U of Manchester	Brazil	UK
City U of Seattle	Bulgaria	USA

Limkokwing U of Creative Tech.	Cambodia	Malaysia
Charles Sturt U	Canada	Australia
DeVry U(closed 2013)	Canada	USA
Fairleigh Dickinson U	Canada	USA
NY Inst. of Tech.	Canada	USA
Potsdam, SUNY (closed)	Canada	USA
U of Phoenix (closed)	Canada	USA
City U of Seattle	Canada	USA
City U of Seattle	Canada	USA
City U of Seattle	Canada	USA
City U of Seattle	Canada	USA
Monash U	China	Australia
U of Tech., Sydney	China	Australia
Fachhochschule fuer Oekonomie und Management	China	Germany
U of Applied Sciences Esslingen	China	Germany
U of Hamburg, Germany	China	Germany
U College Dublin	China	Ireland
Lancaster U	China	Malaysia
Eindhoven U of Tech.	China	Netherlands
Seoul Sunong Trading Company	China	S Korea
U of Ulsan	China	S Korea
Manchester Business School	China	UK
U of Nottingham	China	UK
U of Surrey	China	UK
Carnegie Mellon U	China	USA
Duke Kunshan U	China	USA
Florida Int'l U	China	USA
Fort Hays State U	China	USA
Hult Int'l Business School	China	USA
Johns Hopkins U	China	USA
Kean U	China	USA
Missouri State U	China	USA
NY Inst. of Tech.	China	USA
NYU	China	USA
Webster U	China	USA
Webster U	China	USA
U of Western Ontario	China	Canada
Manchester Business School	China	UK
Savannah College of Art Design	China	USA
Empire State College	Czech Republic	USA

Empire State College	Dominican Republic	USA
Stevens Inst. of Tech. (closed 2010)	Dominican Republic	USA
Universidad Técnica Federico Santa María de Chile	Ecuador	Chile
Brookdale College Ecuador	Ecuador	USA
Tech. U of Berlin	Egypt	Germany
Central Queensland U (closed 2007)	Fiji	Australia
Estonian Business School	Finland	Estonia
U Fernando Pessoa	France	Portugal
Baruch College, CUNY	France	USA
Georgia Inst. of Tech.	France	USA
Parsons - The New School for Design	France	USA
Schiller Int'l U	France	USA
ESMOD	Germany	France
Schiller Int'l U	Germany	USA
Troy U	Germany	USA
Webster U (in development)	Ghana	USA
CMU (closed 2010)	Greece	USA
City U of Seattle	Greece	USA
Empire State College	Greece	USA
Empire State College	Greece	USA
U of Indianapolis	Greece	USA
U of La Verne (closed 2004)	Greece	USA
McDaniel College	Hungary	USA
Sylvan (closed 2004)	India	USA
Texas A&M U (in development)	Israel	USA
Tongji U (in development)	Italy	China
Gonzaga U	Italy	USA
Johns Hopkins U	Italy	USA
U of New Orleans	Jamaica	USA
McGill U	Japan	Canada
Lakeland College	Japan	USA
Temple U	Japan	USA
NY Inst. of Tech. (closed 2013)	Jordan	USA
Lomonosov Moscow State U	Kazakhstan	Russia
Box Hill Inst.	Kuwait	Australia
Soochow U in Laos	Laos	China
Empire State College	Lebanon	USA
Curtin U of Tech.	Malaysia	Australia
Monash U	Malaysia	Australia
Royal Melbourne Inst. of Tech. (closed 1999)	Malaysia	Australia

Swinburne U of Tech.	Malaysia	Australia
Xiamen U (in development)	Malaysia	China
Al-Azhar U (in development)	Malaysia	Egypt
Dublin Business School (closed 2007)	Malaysia	Ireland
Royal College of Surgeons	Malaysia	Ireland
Management Development Inst. of Singapore (in development)	Malaysia	Singapore
Newcastle U	Malaysia	UK
U of Nottingham	Malaysia	UK
U Middlesex London	Mauritius	UK
U of Wolverhampton	Mauritius	UK
Alliant Int'l U	Mexico	USA
Endicott College	Mexico	USA
Arkansas State U (in development)	Mexico	USA
U of Phoenix (closed)	Mexico	USA
Central Queensland U	New Zealand	Australia
Keiser U	Nicaragua	USA
Business School Netherlands	Nigeria	Netherlands
ESMOD	Norway	France
German U of Tech. in Oman	Oman	Germany
Griffith College, Dublin (closed 2006)	Pakistan	Ireland
Monterrey Inst. of Tech.	Panama	Mexico
Empire State College	Panama	USA
Florida State U	Panama	USA
Stockholm School of Economics	Russia	Sweden
Clark U	Poland	USA
College of North Atlantic	Qatar	Canada
U of Calgary	Qatar	Canada
Stenden Hogeschool	Qatar	Netherlands
U London College	Qatar	UK
CMU	Qatar	USA
Cornell U	Qatar	USA
Georgetown U	Qatar	USA
Houston Community College	Qatar	USA
Northwestern U	Qatar	USA
Texas A&M U	Qatar	USA
Virginia Commonwealth U	Qatar	USA
CMU	Rwanda	USA
Monroe College	Saint Lucia	USA
Algonquin College	Saudi Arabia	Canada
Curtin U of Tech.	Singapore	Australia

James Cook U	Singapore	Australia
U New South Wales (closed 2007)	Singapore	Australia
U of Newcastle	Singapore	Australia
Shanghai Jiaotong U	Singapore	China
ESSEC Business School	Singapore	France
INSEAD	Singapore	France
SP Jain Centre of Management	Singapore	India
Manchester Business School	Singapore	UK
Queen Margareth U, Edinburgh	Singapore	UK
Baruch College, CUNY	Singapore	USA
Culinary Inst. of America	Singapore	USA
Digipen Inst. of Tech.	Singapore	USA
NYU	Singapore	USA
U of Chicago	Singapore	USA
U of Nevada, Las Vegas	Singapore	USA
City U of Seattle	Slovakia	USA
Bond U (closed 2004)	S Africa	Australia
Monash U	S Africa	Australia
U of Pune (in development)	S Africa	India
Stenden Hogeschool	S Africa	Netherlands
De Montfort U (closed 2004)	S Africa	UK
Friedrich-Alexander U of Erlangen-Nuremberg	S Korea	Germany
Netherlands Maritime U Rotterdam	S Korea	Netherlands
George Mason U (planned 2014)	S Korea	USA
SUNY-Stony Brook	S Korea	USA
U of Nevada, Las Vegas (in development)	S Korea	USA
U of Utah (pending 2014)	S Korea	USA
Berklee College of Music	Spain	USA
Saint Louis U	Spain	USA
Schiller Int'l U	Spain	USA
U of Central Lancashire (in development)	Sri Lanka	UK
Lynchburg College (in development)	St. Lucia	USA
City U of Seattle	Switzerland	USA
Webster U	Switzerland	USA
Baruch College, CUNY	Taiwan	USA
Lomonosov Moscow State U	Tajikistan	Russia
Beijing Language and Culture U	Thailand	China
Stenden Hogeschool	Thailand	Netherlands
Webster U	Thailand	USA
Webster U	Netherlands	USA

ESMOD	Tunisia	France
Paris-Dauphine U	Tunisia	France
ESMOD	Turkey	France
Empire State College	Turkey	USA
Lomonosov Moscow State U	Ukraine	Russia
U of Waterloo (closed 2013)	UAE	Canada
INSEAD	UAE	France
Sorbonne U	UAE	France
NY Film Academy	UAE	USA
NY Inst. of Tech.	UAE	USA
NYU	UAE	USA
Cambridge College Int'l	UAE	Australia
Murdoch U	UAE	Australia
U of Southern Queensland (closed 2005)	UAE	Australia
U of Wollongong	UAE	Australia
EHSAL-Hogeschool-Universiteit Brussels (closed 2009)	UAE	Belgium
French Fashion U Esmod	UAE	France
Bharati Vidyapeeth U	UAE	India
Birla Inst. of Tech. & Science	UAE	India
Inst. of Management Tech.	UAE	India
Manipal U	UAE	India
SP Jain Centre of Management	UAE	India
Islamic Azad U	UAE	Iran
Royal College of Surgeons	UAE	Ireland
Saint Joseph U	UAE	Lebanon
Shaheed Zulfikar Ali Bhutto Inst. of S&T	UAE	Pakistan
Saint-Petersburg State U of Engineering & Economics	UAE	Russia
U of Sri Jayewardenepura (closed 2009)	UAE	Sri Lanka
CASS Business School	UAE	UK
Heriot-Watt U	UAE	UK
London School of Business	UAE	UK
Manchester Business School	UAE	UK
Middlesex U	UAE	UK
U of Bradford	UAE	UK
U of Exeter	UAE	UK
Boston U (closed)	UAE	USA
Hult Int'l Business School	UAE	USA
Michigan State U	UAE	USA
Rochester Inst. of Tech.	UAE	USA
Vatel Int'l Business School	UAE	France

Madurai Kamaraj U	UAE	India
Mahatma Gandhi U	UAE	India
U of Pune (closed)	UAE	India
Swiss Federal Inst. of Techn., Lausanne	UAE	Switzerland
U of Bolton	UAE	UK
George Mason U (closed 2009)	UAE	USA
Allianze U College of Medical Sciences	UK	Malaysia
Limkokwing U of Creative Tech.	UK	Malaysia
Glion Inst. of Higher Education	UK	Switzerland
Hult Int'l Business School	UK	USA
U of Chicago	UK	USA
Huaqiao U (in development)	USA	China
Glasgow Caledonian U (in development)	USA	UK
U of Manchester	USA	UK
Jose Maria Vargas U	USA	Venezuela
Lomonosov Moscow State U	Uzbekistan	Russia
U of Westminster	Uzbekistan	UK
Plekhanov Russian U of Economics	Uzbekistan	Russia
Management Development Inst. of Singapore	Uzbekistan	Singapore
Royal Melbourne Inst. of Tech.	Vietnam	Australia
Royal Melbourne Inst. of Tech.	Vietnam	Australia
Twintech Int'l U College of Tech.	Yemen	Malaysia
U of London Inst.	France	UK
Aberystwyth U (in development)	Mauritius	UK